Biotic Degradation of Plastic Hygiene Products by Using *Pleurotus ostreatus*

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**Abstract.** Degradation is any physical or chemical adjustment in polymer due to environment factor, such as heat, moisture, light, chemical conditions and biological activity. The aim of this work was to determine the biotic degradation efficiency of plastic hygiene products by using *Pleurotus ostreatus*. Sanitary pads and diapers were used as samples. All the samples will be exposed to the *Pleurotus ostreatus* for 90 days. The degradation efficiencies were analysed based on tensile reduction, morphology and chemical properties of the samples by using universal tensile machine, Scanning Electron Microscope (SEM), Fourier Transform Infrared (FTIR), respectively. The tensile reduction percentage for all samples was increase. The morphology and chemical properties of the samples also showed some changes after undergoes 90 days degradation.

1. **Introduction**

There are various environmental issues being discovered especially from the plastic waste. Hygiene products, which are diapers and sanitary pads, is one of the plastic wastes. These types of plastics waste are non-degradable due to its composition that contains plastic materials such as polyethylene (PE) and polypropylene (PP). It is also containing cellulose and super absorbent polymer (SAP) components. These components are taken a long time to degrade naturally. Due to this, the emission of methane gas will increase the greenhouse effect and eventually global warming. There are ways that have been done previously but it is still insufficient to overcome this problem [1].

The technical improvements have been done to the composition of hygiene products for producing better products especially in size and their efficiency. Even though the components used in the hygiene products still the same, their ratios have varied 80-90% and mixed with additional cotton (fluff cellulose) and fibres (natural or synthetic). Expensive hygiene products normally added a super absorbent polymer such as sodium polyacrylate to increase absorption potential to 500 times its weight in distilled water [2].

Degradation is any physical or chemical adjustment in polymer due to environment factor, such as heat, moisture, light, chemical conditions and also biological activity [3]. Biodegradation or biotic degradation is essential for plastic wastes either for water-soluble or water-immiscible polymer types. The plastic wastes normally will enter streams and then they will neither be recycled nor incinerated. The consideration of microbial degradation of natural and synthetic polymers is crucial due to understanding the fundamental requirement for biodegradation and also their involved mechanisms.
Plastic biodegradations studies have been widely carried out especially to overcome the main issues of environmental problems [4]. Biotic degradation is a condition of degradation where it is happen by using the bacteria or fungus. Mostly bacteria and fungi (microbes) produce normally extracellular enzymes that assistance in degrading various types of polymers.

The cellulose degrading microorganisms could efficiently attack the composition of hygiene products. *Pleurotus ostreatus* is one of microorganisms (fungi) that has potential to degrade cellulosic materials from agro-waste sources by using in situ techniques [5]. Since the uses and production of diapers and sanitary pad increasing every year, there is an urge to study on how to overcome these types of plastics waste problem and environmental issue. There are several studies done according to these environmental issues that are using the microbes to degrade the plastics waste. However, some microbes used are not efficient to degrade the plastics waste. Thus, it is important to do study on this matter by using plastic waste types which is hygiene product to overcome this solve environmental issues.

2. Methodology

2.1. Chemicals
Ammonium chloride (NH₄Cl), magnesium sulphate (MgSO₄), potassium phosphate (KH₂PO₄), sodium chloride (NaCl) and sodium phosphate (Na₂HPO₄) and calcium chloride (CaCl₂) were used in biotic degradation.

2.2. Potato Dextrose Agar (PDA) preparation
The 37 gram PDA powder was weighed using analytic balance and added with 1 L distilled water into a conical flask. The mixture of PDA powder and distilled water was sterilized by autoclaving at 121 °C for 15 minutes. The solution (media) was poured into the petri dishes. Petri dishes were sealed by using parafilm to avoid contamination.

2.3. Subculture preparation
Agar that contain mycelium of *Pleurotus ostreatus* were cut using scalpel and transferred to the PDA agar medium.

2.4. Minimal media Agar preparation
500 ml of M9 components (minimal salt) was prepared by weighted 6 g of Na₂HPO₄, 3 g KH₂PO₄, and 0.5 g NH₄Cl into 500 ml of volumetric flask. Distilled water was added up to 500 ml. For agar preparation, 16 g agar was weighted, and distilled water was added up to 500 ml volumetric flask. Both of M9 components (minimal salts) and agar was autoclave at 121°C and 15 minutes. Once cooled to 55 °C, agar and M9 components (minimal salts) were mixed. Next, the following sterilize ingredients, which is 1 mL 1M MgSO₄ and 1 mL of 0.1M CaCl₂ were added into the mixture media. All the mixture were mixed and poured into the petri dish [6].

2.5. Samples preparation
Samples used in this study were sanitary pads and diapers from two different brand: Drypers and Giant diapers. The front parts each of the samples, which contain PE and PP plastics, were used in this study. Sanitary pads and diapers fragments with the weight around 10 g were cut (4cm x 4cm) using scissor and then the samples were placed on the top surface of the minimal media agar. The mycelium was placed at the top of samples surface. The samples was placed in the dark cabinet for 30, 45, 60, 75, and 90 days.

2.6. Analysis procedure

2.6.1. Mechanical properties analysis. All types of degradation undergoes mechanicals properties analysis by resulting the tensile strength reduction (%). Two samples for each types of degradation
undergoes this analysis. Mechanical properties analysis were done before the degradation process, after 45 days and 90 days degradation. Tensile strength reduction is determined using the formula as shown below [7].

\[
\text{Tensile reduction} = \frac{\text{Initial tensile strength} - \text{Final tensile strength}}{\text{Initial tensile strength}} \times 100\% \quad (1)
\]

### 2.6.2 **Morphology analysis by SEM.** The samples were cut to 1 cm x 1 cm size where it underwent morphology analysis using 1000x magnification of SEM, Hitachi TM 3000 Tabletop.

### 2.6.3 **Weight loss analysis.** Samples were weight using analytical balance where the mycelium on the surface of the samples was removed first. The samples then washed and dried for 30 minutes. Weight of the samples was taken after 30, 45, 60, 75, and 90 days of degradation. The weight loss of the samples determined using the formula given as shown below [8].

\[
\text{Weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100\% \quad (2)
\]

### 2.6.4 **FTIR analysis.** FTIR was used to analyse the chemical properties of the samples such as the disappearance or formation of new functional groups and bond session of the samples. FTIR spectra were recorded at room temperature by using a FT-IR spectrometer (PerkinElmer Inc., Waltham, MA, USA) in attenuated total reflectance (ATR) mode from 650 to 4000 cm\(^{-1}\). ATR spectra were collected on the surface of the sample before and after biotic degradation.

### 3. Results and Discussion

*Pleurotus ostreatus* is a biodegrader that used in this study in order to analyze the biotic degradation for plastic hygiene products for 90 days degradation. All samples were taken every 15 days interval until 90 days for analyzing degradation efficiency.

#### 3.1. **Tensile reduction (%)**

Figure 1 shows the tensile strength reduction in percentage (%) for all the samples. As shown in the Figure 1, Drypers diapers resulted 100% in reduction of tensile strength (fragmentation) after undergoing 90 days biotic degradation. Meanwhile, the Giant diapers and sanitary pads contribute to 17.35% and 16.20%, respectively. Tensile reduction occurred due to the existence of fungus growth on the surface of the samples [9]. In theory, principle mechanisms of polymer biodegradation is when microbes stick with polymers followed by surface colonization [10]. The extracellular enzymes that produced by fungi also support the degrading of polymer. In the enzyme-based hydrolysis consists of two steps which are the enzymes attached to the polymer substrate followed by hydrolytic division.

Research that have been made by the Da Luz et al., (2015) showed decreasing result in biotic degradation using green PE as a samples [11]. This also proved that the samples can be as a carbon source and allowed the Pleurotus ostreatus to grow on the surface of the samples.
3.2. Morphology of the samples by SEM
Figure 2 shows the morphology of sanitary pads, Drypers diapers, Giant diapers before and after biotic degradation. Figure 2 (b), (d) and (f) show morphology of surface after 90 days of degradation. Figure 2 (d) shows the severe degradation compared to (b) and (f). This observation may reflect the result from the percentage tensile reduction (100 %) for Drypers diapers sample which after 90 days the fragmentation was occurred. From Figure 2 (b), (d) and (f) also proved that Pleurotus ostreatus are grew and colonized on the surface of the samples. Special ability of this types of fungus also mention in previous research that state that Pleurotus ostreatus species is a white rot fungi that have characteristic to degrade the polymer as the polymer have same structural of lignin [12].

![Figure 1. Tensile reduction of biotic degradation](image)

![Figure 2. (a) Sanitary pads 0 days, (b) Sanitary pads 90 days, (c) Drypers diapers 0 days, (d) Drypers diapers 90 days (e) Giant diapers 0 days, (f) Giant diapers 90 days](image)
3.3. Weight loss of the samples

All the samples undergo biotic degradation for starting from 30 to 90 days. Figure 3 showed the weight loss for all samples slightly increase during that period which contributed to 31%, 39% and 46% (sanitary pad, Giant diapers and Drypers diapers). *Pleurotus ostreatus* is white rot fungi that can degrade PE and PP that mostly found in all samples. According to the previous study by Rodrigues et al. (2013) and Jones et al. (2017) all those samples that contained PE & PP acted as a carbon sources where *Pleurotus ostreatus* can growth by absorbing the carbon sources due to it saprotrophic characteristics [13, 14]. *Pleurotus ostreatus* also capable to degrade lignin and these ability make this types of fungus can degrade the certain types of plastics. Molecule structure of PE and PP are types of plastic that have similar molecules with lignin.

This finding is in agreement with previous study done by Da Luz et al. (2015) on degradation using green PE as a sample where the weight loss result for biotic degradation using *Pleurotus ostreatus* after undergoes 120 days degradation [11]. It proved that *Pleurotus ostreatus* could degrade the samples that mostly made up from PE & PP without using any prior physical treatment such as exposure to the sunlight.

There are decreasing weight loss resulted for Drypers diaper and Giant diaper after 75 days. Decreasing weight loss is due to the fungi stationary phase at that time which are the fungi consume less samples as a carbon sources [15]. However, the fungi growth phase on sanitary pads takes a longer time and slower degradation rate as resulted a lower weight loss compared to the other two samples. It is due to the adhesive tape on the surface of the sanitary pads, and those types of material uneasy to degrade.

3.4. Chemical properties of the samples by FTIR

Figure 4, 5 and 6 show the FTIR spectra for sanitary pads, Drypers diapers and Giant diapers samples, respectively in 0 and 90 days. For sanitary pads, the intensity of the band are decreased at peak 2866 cm\(^{-1}\) to 2854 cm\(^{-1}\) attributes to the C-H alkanes stretch after undergoing biotic degradation. The decreasing intensity of the band also happen at the peak 1031 cm\(^{-1}\) until 1452 cm\(^{-1}\) may due to the activity of the fungus growth on the surface of the samples. It supported by the formation of the peak at 3450 cm\(^{-1}\), which is slightly decrease bending as shown in Figure 4 (b). However, the bond is not break completely, it is only make are a bit changes There are also new functional group at peak 1648 cm\(^{-1}\) which involved C=O amide stretch.

![Figure 3. Weight loss of sample in biotic degradation.](image-url)
Figure 4. FTIR spectra of biotic degradation for (a) control (0 day) and (b) 90 days of sanitary pads samples.

Figure 5. FTIR spectra of biotic degradation for (a) control (0 day) and (b) 90 days of Drypers diapers samples.

Figure 6. FTIR spectra of biotic degradation for (a) control (0 day) and (b) 90 days of Giant diapers samples.
Figure 5 (b) showed that Dypers diapers formation of hydroxyl group (O-H) stretch at the peak 3335 cm\(^{-1}\). This showed that oxidation reaction happen [16]. The new functional group for this samples showed at the peak 1665 cm\(^{-1}\) which attributed to the C=O ketone stretching. The formation of the carbonyl group after degradation is due to the microbial enzymatic activities [17]. The C-H stretch is decreasing after undergoes biotic degradation at the peak 2918 cm\(^{-1}\). The intensity of the peak decreased due to the *Pleurotus ostreatus* fungus attacked the bond. The peak at the 1062 cm\(^{-1}\) attributed to the C-O bending which is the formation of ester group and cause decreasing hydrophobicity of the surface thus favoring biotic degradation [9].

The decreasing result for intensity of the band also showed for Giant diapers at the peak 2850 cm\(^{-1}\) – 2917 cm\(^{-1}\) as shown in Figure 6 (b). The new functional group are showed at the peak 1645 cm\(^{-1}\) which attributed to the carbonyl group (C=O) stretch that represented amide group. The intensity of the band also showed for Giant diapers at the peak 2850 cm\(^{-1}\) – 2917 cm\(^{-1}\) as shown in Figure 6 (b). The new functional group are showed at the peak 1645 cm\(^{-1}\) which attributed to the carbonyl group (C=O) stretch that represented amide group. The intensity of the band also showed for Giant diapers at the peak 2850 cm\(^{-1}\) – 2917 cm\(^{-1}\) as shown in Figure 6 (b).

4. Conclusion
The Drypers diaper shows higher degradation efficiency as compared to sanitary pad and Giant diapers based on the higher tensile reduction, higher weight loss, showed more cracks and hole at the surface and formation of the carbonyl group for the chemical properties. It also can prove the ability and efficiency of the *Pleurotus ostreatus* to degrade the plastics hygiene products (PE and PP).

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