Production and Characterization of Biofilms using Biomass Waste

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Abstract

Most plastics that are available in the market are mainly made of petroleum. Therefore, it is difficult to degrade even after long exposure in land or sea. This will leave a negative impact to the environment while contributing adverse effects on living things. If the petroleum-based plastic were burned, they will cause air pollution that may lead to other health effects. There are cases where animals, marine and land, which eat the plastic and die due to their inability to digest them in their stomach. Thus, biodegradable plastic or biofilm are produced as it is beneficial to the environment due to its high degradability. This study focus on the feasibility of bioplastic made from Jackfruit seed and cassava peel, as they can be easily found, thus can help in improving the management of agricultural waste in Malaysia. This paper study the physical abilities of biofilm made from two different sources of starch; jackfruit seed and cassava peel in different concentrations; 1, 3 and 5 grams. The starch was mixed with chitosan and glycerol as plasticizer. The biofilms were tested for their tensile strength, elongation at break test, and their degradability ability via the soil burial method. As a conclusion, jackfruit seed is a better choice as raw materials for starch compared to the cassava peels as it produced a stronger biofilm with more flexibility and a higher degree of degradability. This may be due to the higher concentration of starch in the jackfruit seed as compared to the cassava peels..

Keywords: Biofilm, Cassava Peel Starch, Jackfruit Seed Starch

1. Introduction

Plastics have become a vital part of everyday life and our dependency towards it is increasing, prompting its increased in production to exceed 250 million tonnes by 2009 with an annual increased rate of 9% (Ogunola, Onada, & Falaye, 2018). A study has shown that 275 million metric tons (MT) of plastic waste was generated in 192 coastal countries in 2010, with 4.8 to 12.7 million MT estimated to be entering the ocean (Jambeck et al., 2015). The remainder stayed in lands, which will be usually managed using current trends in the plastic waste management either by landfilling; which required a vast amount of space and cause reduction in soil fertility, emission of toxic gases and pollution of ground water due to leaching of the chemicals from the waste, incineration; which provides energy but also contributes to gas pollution, recycling; which required proper sorting of the plastics or biodegradable plastics, which decomposed by living organisms (North & Halden, 2013).

A survey of 60 cities in India by the Central Pollution Control Board estimated that about 33.7 million pounds of plastic waste was generated each day with about 13.2 million pounds of those remaining uncollected and littering roads (Elena-Diana, Hlihor, Ghinea, & Gavrilescu, 2016). Due to the increasing problem of plastic wastes, some state governments in Malaysia have introduced the ‘No Plastic Bag Day’ and #BebasPlastik campaign to reduce the amount of plastic usage among Malaysian consumers. However, the state government found that 71% of people felt that the "No Plastic Bag Day" on Saturdays was insufficient (Khoramnejadian, Zavareh, & Khoramnejadian, 2011).

A substitute for plastic has to be introduced to reduce the plastic waste in the country and in the world. One of the substitute is bioplastic film. Biofilm are plastics derived from renewable biomass sources and its market is thought to be growing at a rate of 20 %– 25%per year (Ezgi Bezirhan & Havva Duygu, 2015). There are four types of degradable plastics depending on their materials and the degradability capability which are photodegradable bioplastics, plant-derived bioplastics, compostable bioplastics and biodegradable biofilm. The bio-based plastics are most preferable in The Plastic Spectrum (Rossi, 2005) as it has the least impact to human health and environment. Bio-based plastics are preferable as it used materials grown without genetically modified organisms (GMOs), hazardous pesticides, certified as sustainable for the soil and ecosystems, and compostable into healthy and safe nutrients for food crops (Rossi & Lent, 2006). Starch, which is a natural biodegradable polymer has been reported to be one of the most promising candidates for fabrication of bioplastics (Huang, Yu, & Ma, 2004). One of the most abundantly found source of starch in Malaysia is cassava. Cassava is tuber plant that is rich in carbohydrate (Fauquet & Fargette, 1990) and serve as one the staple food in the world, providing a basic diet for over half a billion people. On the other hand, jackfruit is a fruit that most commonly found in tropical lowlands area. Its seeds are high in starch and are often cooked as snacks or processed to be flour. However, it has been found that, a lectin specific for N-acetylgalactosamine could be isolated from seed extract of Jackfruit which possessed agglutinating activities for human and rat sperm as well as human red blood cells (Namjuntra, Muanwongyathi, & Chulavatnatol, 1985).

Due to their high abundance in Malaysia, cassava peel and the jackfruit seed were chosen as the raw materials for the development of bioplastics. These two materials are waste, and its alternative usage may help in a more efficient waste management. This paper focus on the physical capabilities of bioplastics derived from cassava peel and jackfruit seeds.

2. Methodology

2.1 Materials

Cassava peel and jackfruit seed used was obtained from nearby chip making factories. Chitosan (deacetylated chitin) was purchased from ALDRICH Chemistry, while acetic acid and glycerol were purchased from QREC (Asia) Sdn Bhd and HmbG Chemicals, respectively. The soil used for the biodegradability test was taken from the field nearby the Polytechnic's campus.

2.2 Extraction of Starch from Cassava Peel and Jackfruit Seed

This extraction of starch method was referred to Belibi *et al.* (2014). Firstly, cassava peels and jackfruit seed were washed with tap water and dried under a hot sun. The cassava peels and jackfruit seed were cut in order to reduce its size. Then, 300 g of cassava peels and jackfruit were added with distilled water with comparison of 1:1 and blended by using blender, separately. The slurry obtained was filtered by using a filter cloth and Filtrate I and Waste I was produced. After that, water was added to Waste I of cassava peel and jackfruit seed from the first filtrated with ratio of 1:1, and then sedimentation was carried out and continued by filtration. Thus, Filtrate II was obtained for both, cassava peels and jackfruit seed. Precipitation of Filtrate I and Filtrate II were mixed and waited for 3 hours in order to obtain starch deposited. Next, the starch deposited was dried in the drying oven at temperature of 60°C for 6 hours for removal of free water. Lastly, an Iodine test was conducted to test the presence of starch.

2.3 Biofilms Preparation

The biofilms were prepared using the casting technique, with modifications to the method described by and Araujo-Farro *et al.* (2010). Cassava peel starch was dissolved in distilled water at concentration of 1, 3 and 5 g/100 mL by heating the mixtures on hot plate and stirred at temperature of 85 ± 2°C for about 5 – 15 minutes. The chitosan solution were prepared by dispersing 2 g of chitosan in 100 mL of acetic acid (1% v/v) and stirred until it completely dissolved. A series of cassava peel starch-chitosan blend were prepared by mixing 100 mL of starch solution (1, 3 and 5 g/100 mL) with 100 mL of the starch solution (2 g/100 mL). The solutions were mixed by gentle stirring with a magnetic stirrer until the solution becomes homogenized. Glycerol was added as 40% (w/w) of the total solid weigh of cassava peel starch. The resulting solutions were degassed for several hours for bubbles removal. Then, the solutions were poured and casted onto flat, levelled, non-stick glass Petri dishes and leaved it in drying oven at temperature of 60°C for 5 hours. After drying, the biofilm was peeled off from the glass Petri dish. The same procedures were repeated for jackfruit seed starch.

2.4 Mechanical Properties

The tensile strength and elongation at break were performed using Universal Testing Machine brand Shimadzu, fitted with 5kN static load cell. The biofilms were cut into dumbbell shape with 1.5 cm wide and 6.5 cm long. The tensile properties were measured at a crosshead speed of 1 mm/ min and an initial grip separation of 100 mm.Tensile strength and elongation at break tests were replicated three times for each type of biofilm.

2.5 Biodegradability Test

Soil burial degradation was performed as described by Mostafa *et al.(2018)*. The medium size of recycle bottle (pot) was cut and filled with soil taken from field nearby Nilai Polytechnic. The films were cut into 3 cm x 3 cm pieces, weighed and buried in the soil at depth of 5cm. The pots were placed in an uncovered place. The degradation of the films was determined at a regular time interval (3 days) by taking the films carefully from the soil and washed it gently with distilled water to remove the soil. The films were dried in a drying oven until constant weight was obtained. Weight losses of the films with time were used to indicate the degradation rate in the soil burial test.

3. Results and Discussion

3.1 Appearance of the Biofilms

All starch-chitosan biofilms were between yellowish to brown-yellowish in appearance. The results showed that the starch concentration significantly affects the color of the biofilms. As the concentration of starch increased, the color surface turned darker; from yellowish to brown-yellowish. The changes in color were attributed by the extracted starches which is light brown in color and also chitosan which is pale yellow in color.

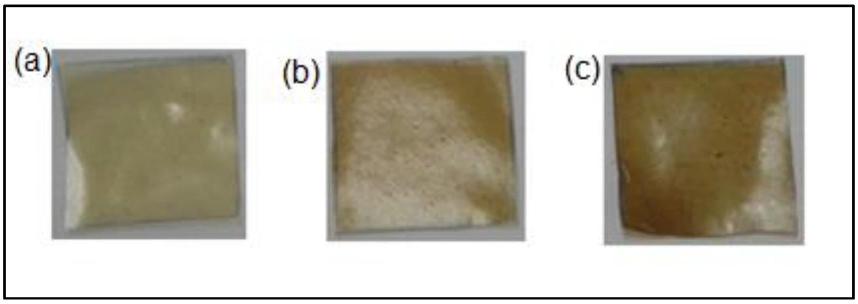

Figure 3.1. Appearance of biofilms from cassava peel starch; (a) 1% w/w starch-chitosan film, (b) 3% w/w starch-chitosan film, (c) 5% w/w starch-chitosan film

Figure 3.2. Appearance of biofilms from jackfruit seed starch; (a) 1% w/w starch-chitosan film, (b) 3% w/w starch-chitosan film, (c) 5% w/w starch-chitosan film

All films were transparent, thin-layer, flexible, elastic and easy to handle. The starch-chitosan blend films showed smooth and homogenous texture. This shows good compatibility between the hydroxyl groups of starch and the amino groups of chitosan (Elsabee & Abdou, 2013; Shapi'i & Othman, 2016). According to Lee, Yam & Piergiovanni (2008), transparency of films can be affected by the homogeneity and amount of inert filler such as chitosan.

3.2 Mechanical Properties

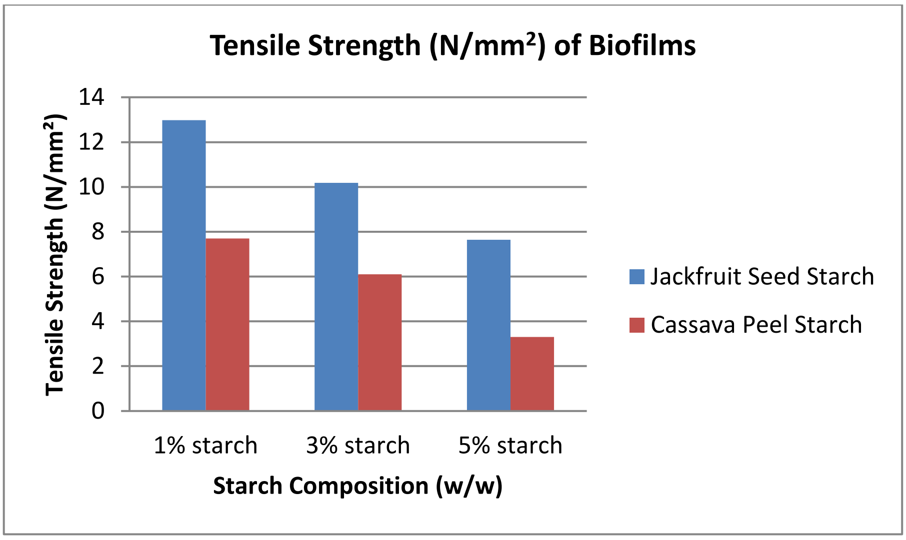

Figure 3.3 Tensile strength of the biofilms showing the decreasing tensile strength with increasing concentration of starch

Figure 3.3 and Figure 3.4 shows the effect of different types of starch and concentration of starch on the tensile strength (TS) and elongation at break (EAB) of the biofilms.It can be seen that, the TS of jackfruit seed starch-chitosan blend films is much higher than cassava peel starch-chitosan blend films. The differences occurred due to different contains of amylose and amylopectin percentage in both starches. Despite of that, both types of starch-chitosan blend films (jackfruit seed starch-chitosan and cassava peel starch-chitosan) shows higher TS at 1% w/w of starch content with a maximum value of 12.98 N/mm^2 and 7.7 N/mm^2, respectively.

The maximum value of TS was attributable to a high formation of inter-molecular hydrogen bonding between NH_3^+ of the chitosan backbone and OH^- of the starch. When strong intermolecular bonding between molecules formed, the film exhibited strong affinity and high tensile strength. However, as the starch concentration increased, the TS decreased because starch intra-molecular hydrogen bonds are formed rather than inter-molecular hydrogen bonds, resulting in a phase separation between the two main components (Xu, Kim, Hanna, & Nag, 2005).

The excessive addition of starch will lower the flexibility of the sample. The starch chains could be degraded when exposed to high temperature and shear stress, thus can decrease the tensile strength of the samples. The use of glycerol also can affect the tensile of the sample. The addition of plasticizer, like glycerol increase the flexibility of the samples but will reduce the intermolecular forces.

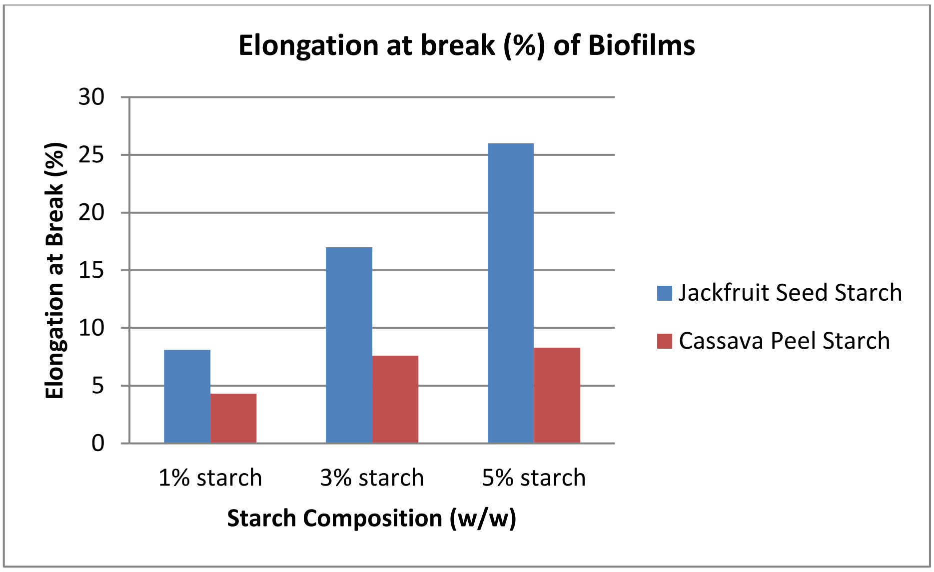

Figure 3.4. Elongation at break of the biofilms showing the increasing elongation at break with increasing concentration of starch

As can be seen in Figure 3.4, EAB values of films increased with the increase of starch concentration in biofilms.A mathematical modeling study by Chillo *et al.* (2008) had proven that improvement of EAB only influenced by the amount of plasticizer particularly glycerol concentration. The EAB value for 5% w/w of jackfruit seed starch-chitosan blend film (26%) and 5% w/w of cassava peel starch-chitosan blend film (8.3%) increased by 18% and 4%, respectively compared to 1% w/w of starch-chitosan blend film. Phase separation of both starch and chitosan compounds led to less affinity between the molecules. Therefore, the molecules arrangements were less compact and became more flexible compared to 1% w/w of starch-chitosan blend film (Shapi'i & Othman, 2016).

3.3 Biodegradability Test

Figure 3.5 showed the compactness of starch-chitosan blend films before and after soil burial test. The transparent films began to degrade in 3 days and become darker in color over time. The films were eroded significantly and lost their original shape as the soil burial time increased. The films appeared brittle, fragile and diminished in size indicating the natural biodegradation of these films in the soil environment.

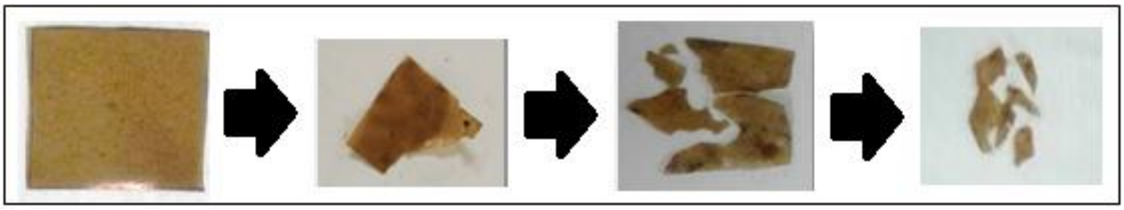

Figure 3.5 The integrity of film samples before and after the soil burial test showing the films losing their shape along the time their being buried.

The evolution of the degradation in soil of the biodegradable films during the experimental period was shown in Figure 3.6. It can be seen that the biodegradability increased as the burial time increased. The graph has shown that after 12 days of burial time, jackfruit seed biofilms shown a higher rate of degradation rate as compared to the cassava films with 5% jackfruit at 96%, 3% jackfruit at 94%, 1% jackfruit at 87%, 5% cassava at 86%, 3% cassava at 41.81% and 1% cassava at 25.44%. Hence, this shown despite the materials used, the degradation rate will increase with higher concentration of starch in the biofilms.

The films initially showed faster degradation behavior and after certain time period, the degradation becomes slower. This rapid degradation was due to the composting process, which occurred in two main stages: an active composting stage and a curing period. In the first stage, the temperature rose and remained elevated as long as there was available oxygen, which resulted in strong microbial activity.

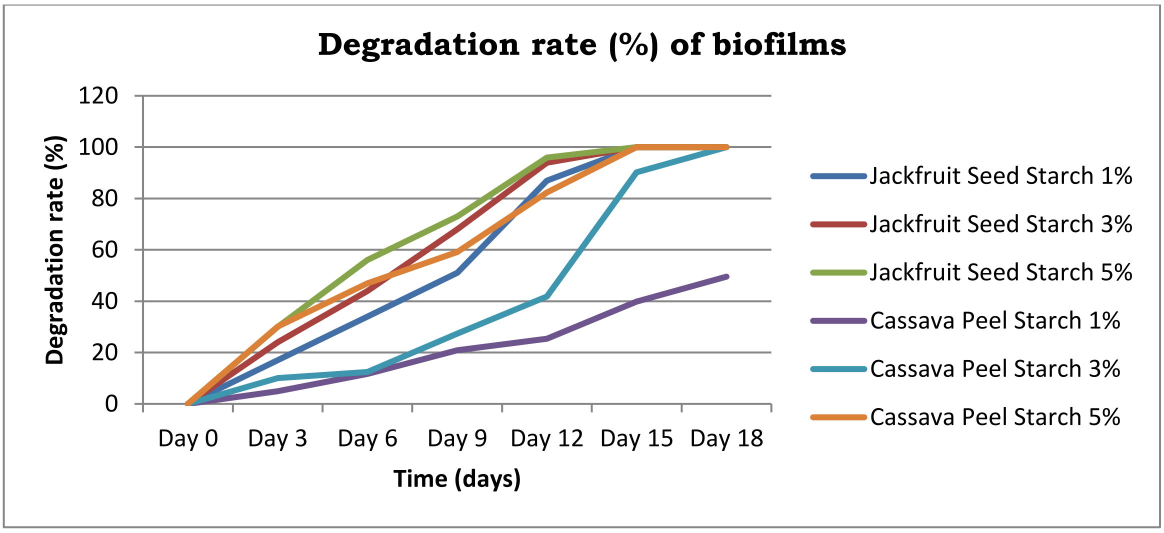

Figure 3.6 Degradation rates (%) of biofilms in soil as days are increased.

In the second stage, the temperature decreased but the film continued to compost at a slower rate until the last remaining nutrients were consumed by the remaining micro-organisms and almost all of the carbon had been converted into carbon dioxide (Azahari, Othman, & Ismail, 2011; Jaafar, Majeed, & Kamil, 2014).

The decreases in weight loss of the biofilm were due to the microorganisms that present in the soil (Kolawole, Igwemmar, & Bello, 2013). The microorganisms feed on the starch in the biofilm, thus, resulting in the loss of their structural characteristics (Bernard, 2014) The major constituents of starch can be degraded by many bacteria and fungi in the soil environment (Shahin, Kazmi, & Ali, 2012). Microorganisms can attack the polymers into digestible units, so that starch structure is weakened and starch strength is reduced (Shimao, 2001).

4. Conclusion

As a conclusion, jackfruit seed is a better choice as raw materials for starch as compared to the cassava peels as it produced a stronger biofilm with more flexibility and a higher degree of degradability. This may be due to the higher concentration of starch in the jackfruit seed as compared to the cassava peels. However, selection of raw materials should not only consider the strength of the biofilms produced, but the availability of the raw materials and the overall impact of the usage of the materials should also be taken into consideration.

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