Synthesis of biodegradable starch-chitosan blend plastic film by casting technique

Liew Meei Shuenn[a], Lau Kam Sheng[b], Chong Mee Yoke[c], Evyan Yang Chia-Yan[*a]

[a]School of Applied Sciences, Faculty of Engineering, Science and Technology, Nilai University, 71800 Nilai, Negeri Sembilan, Malaysia
[b]Department of Applied Physics, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.
[c]Centre for American Education, INTI International University, 71800 Nilai, Negeri Sembilan, Malaysia

[*]Corresponding author and e-mail: Evyan Yang Chia-Yan, evyanyang@nilai.edu.my

Abstract

Plastic packaging plays several important roles in our modern life including food which occupy more than 50% plastic usages around the world. Plastic is non-biodegradable and its decomposition may take up few decades or even few centuries. Biodegradable plastic has replaced the ordinary plastic in order to overcome the problems of pollution since decade ago. However, researchers are still working on the optimization of properties and synthesis methods of biodegradable plastic. In this study, biodegradable plastic was synthesized using starch and chitosan by simple casting method. The optimisation of the samples was made based different ratio of corn starch and chitosan in the polymer blend. The characterization was carried to measure the properties of mechanical, absorption and biodegradability. From the results, plastic film with 40% corn starch and 60% chitosan performed the highest tensile strength ranges between 36 – 37MPa meanwhile it possessed the highest degradability. The thickness of the film tends to increase with the increment of corn starch. Plastic film with 60% corn starch and 40 % chitosan exhibited the highest water absorption. The study outlined that chitosan was found to be a strong reinforcing agent for starch-based biodegradable films. The content of corn starch may vary depending on the usage of the packaging or film. The biodegradable corn starch-chitosan plastic films could be promoted towards green environment without carbon release.

Keywords: *Biodegradable; Adsorption; Mechanical properties*

1.0 INTRODUCTION

The success of plastics starting in the early 20th century that formed by crude oil has led to its uncontrolled usage for many decades. The fact that plastics cannot be decomposed for thousands of years, they are now considered an absolute threat to the environment. Recycling has been practiced since 1970s in order to solve this problem. Scientists have come up with biodegradable polymers and has been undergone wide-ranging exploration. Biodegradable polymers are polymers which can breakdown its components into natural by-products (Craftechind, 2019). The introduction of biodegradable materials which can be disposed directly into the soil becomes one of the solutions to overcome the environment pollution problems.

Basically, the biodegradable plastic or film can be classified into bio-based plastic and petroleum-based plastics. The classification of the plastic is based on the raw materials, namely bio-based and petroleum-based. Bio-based plastics are made from plant-based sources, like starch and cellulose meanwhile petroleum-based plastics are polymers made from petrochemicals（Evyan et al., 2021）. The raw materials to produce bio-based plastic/ polymer are low cost and some even are abundant materials especially cellulose. There are thermoplastic polymers produced by blending of starch, chitosan or cellulose as the raw material of plastic productions.

Natural polymers such as starch have been frequently known as alternatives to plastics derived from petroleum in the production of packaging films. Recently more effort has been put to grow polymeric materials from renewable resources which are environmentally compatible to replace petroleum-based synthetic polymers. Some renewable materials are comparatively less expensive, environmentally friendly and naturally biodegradable (Chisenga, et al., 2020). Starch is insoluble in most organic solvents and water. The starch will be stable in storage for indefinite periods in dry condition. They can be disrupted easily, even though starch granules are physically durable. Chitosan is a linear natural polycationic polysaccharide. Chitosan derived from chitin and chitin is the second most abundant natural amino polysaccharide (Surinder et al., 2015). It is a new functional material of high potential in various biodegradability, non-toxicity and low allergenicity. New functional properties were created after the chemical modification into composites or hydrogels which can be applied in various field especially in pharmaceutical and biomedical (Randy et al., 2015).

Blending of biopolymer with another polymer which is not necessarily a biodegradable polymer is an effective way to change its properties (Niaounakis, 2017). In this study, biodegradable plastic film will be prepared by blending of corn starch and chitosan based on different composition. The factors that influence the properties of the film has been investigated based on the composition of corn starch and chitosan. It is aimed to produce biodegradable plastic film depending on the application towards green and sustainable environment.

2.0 METHODOLOGY

Chitosan solution is prepared using chitosan powder (Sigma-Aldrich) and distilled water with ratio of 1:99. A desired amount of corn starch (CS Market) dissolved in the de-ionized water with constant stirring on the hotplate at 70°C. The solution was then poured into non-stick pans to form the film by casting method. The samples were synthesized using corn starch and chitosan solution at different percentage respectively as in Table 1 by repeating the same procedures. The volume of the solution was kept constant in order to maintain the thicknesses of the film.

Table 1. Ratio of corn starch and chitosan in each sample.

Sample	Corn Starch (%)	Chitosan(%)
CCH2:8	20	80
CCH4:6	40	60

CCH6:4	60	40
CCH8:2	80	20
CCH9:1	90	10

The standard for tensile test was set according to ASTM D882-12 using Universal Testing Machine (Gotech AI-3000) (Evyan et al., 2017). The thicknesses of the films were measured using micrometre screw gauge (0-25±0.001mm) by measuring the thickness of five points and the average thickness for each sample was calculated. The samples were observed under optical microscope with the lens power of 4x and 10x and compared among samples with different ratio of corn starch and chitosan. In biodegradable test, the samples were buried at the depth of 10cm in the soil. The pots were kept indoor for 7 days and the weight loss of the samples were observed daily within the 7 days and measured using the Eq. (1) (Khan, et al., 2016):

$$\%\text{Weight loss} = \frac{W_b - W_a}{W_b} x\ 100\% \qquad \ldots.(1)$$

where Wb= weight before placement in soil Wa= weight after taken out and cleaned

3.0 Results and Discussion

The tensile strength of a material refer to the highest value of tensile stress that can be withstood by the material just before breaking. The samples which synthesized according ratio of corn starch and chitosan were measured for their average tensile strength as in Table 2.

Table 2. Average tensile strength for the samples according to the ratio of corn starch and chitosan.

Sample	**Tensile Strength (MPa)**
CCH2:8	37.13 ±1.96
CCH4:6	37.23±0.84
CCH6:4	27.80±2.92
CCH8:2	37.40±1.20
CCH9:1	24.40±3.11

The addition of chitosan to the biofilms obviouly affected by tensile strength. The presence of chitosan promotes an incensement of tensile strength. The starch-based films are brittle at 20% chitosan content. Tensile strengths of starch-based films were increased with the amount of chitosan. The higher content of chitosan will cause the higher the stiffness of the films (Mendesa, 2016). This reflect in the result in Table 1, 40% corn starch, 60% chitosan show that the tensile strength ranges between 36 – 37MPa with the presence of chitosan caused an increase in the tensile strength.

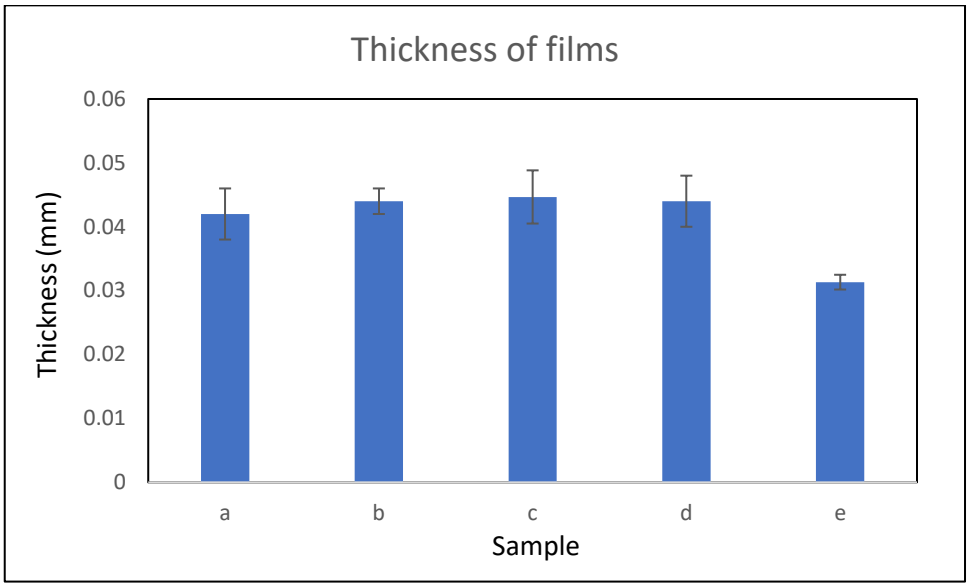
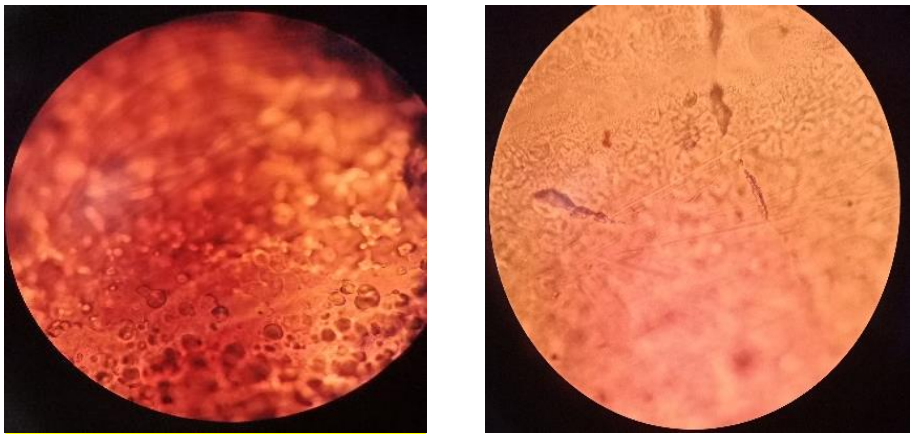


Fig. 1. Thickness of the samples of: (a) CCH2:8; (b) CCH4:6; (c) CCH6:4; (c) CCH6:4; (d) CCH8:2 and (e) CCH9:1

In Fig. 1, the thinnest film is the film that formed with 40% corn starch and 60 % chitosan while the thickest film is the film that formed with having 60% corn starch and 40% chitosan. The thickness of the film tends to increase with the increment of chitosan. During gelatinization process, starch clotting takes place when denaturization is happened. The clotting of starch forms water-absorbent gel. It is noticed that the mechanical properties of the films are also affected by the thickness of the film (Asria, 2016).

The morphology of the samples can be seen in Fig. 2. In the first set of starch/chitosan film shows inhomogeneous structure with small particles distributed on the film surface, it indicated that not all chitosan dissolved in acetic acid solution. In order to enhance the formation of fine structure during casting of the films was by increasing the temperature to 80°C and the by stirring the mixture using magnetic stirrer (Shapi and Othman, 2016).

The measurement of biodegradability is to calculate the ability of materials to be analysed into simpler substances through the action of enzymes by microorganisms. The film was totally disappeared after 5th day of burry only CCH2:8 not degraded. The degradability of all the samples displayed in Fig 3. It was observed that the weight loss percentage is increased with the increasing of time. After 7 days, it was found that the films totally degraded in the soil and could not see any portion of the film. Degradation of the films happened as a result of the discontinuation of starch location occupied by either microbe or water. Water absorb by the polymer blends which led the blends swelling and thus accelerate degradation (Henry et al., 2015). Polymers that are based on naturally grown products such as starch are prone to microorganism's degradation. Microorganisms can attack the polymers carbohydrates and have very particular enzymes capable of hydrolysing these polymers into digestible.



(a) (b)

Fig. 2. Images of the samples at magnification of 100x: (a) CCHH9:1 stirring at room temperature and (b) CCHH9:1 stirring at 80°C

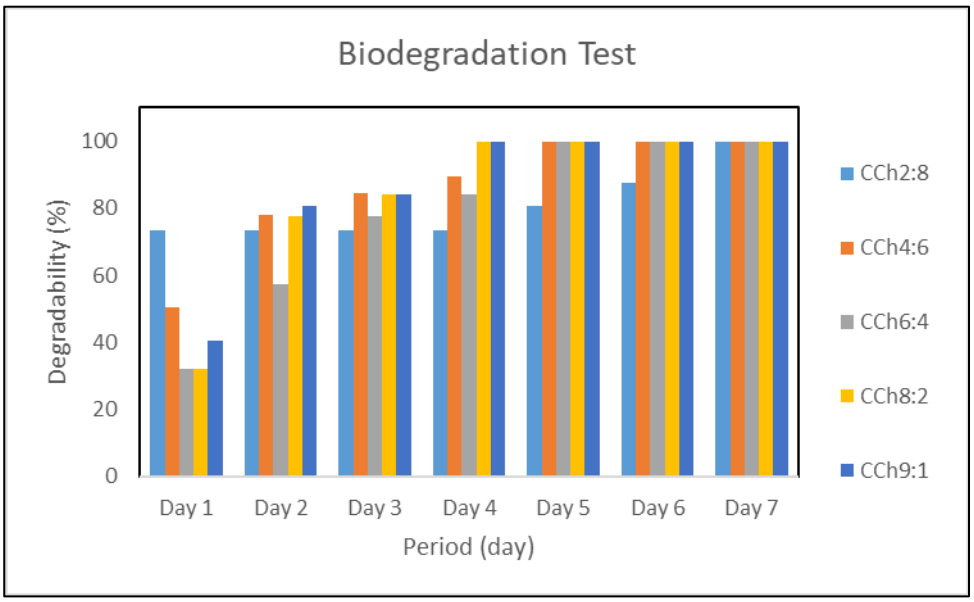


Fig. 3. Biodegradability of the samples of: (a) CCH2:8; (b) CCH4:6; (c) CCH6:4; (c) CCH6:4; (d) CCH8:2 and (e) CCH9:1

4.0 CONCLUSION

The biodegradable film made of starch and chitosan was successfully developed by casting method. Chitosan was found as a strong reinforcing agent for starch-based biodegradable films. The yellow colour of the film become darker as the composition of corn starch increases. Ratio of corn starch: chitosan influences tensile strength ability of water absorption of the films. The sample with 40% corn starch and 60% chitosan performed the highest tensile strength due to chitosan acted as reinforcing agent in starch based biodegradable films. Meanwhile the composition of corn starch increases the ability of water absorption of the film up to ratio of 60% corn starch and 40% chitosan. The composition of starch and chitosan need to be varied based on

specific application. Further study should be carried out to enhanced the plastic film with added value such as antimicrobial and higher degradability in shorter duration.

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