Malaysian Journal of Chemical Engineering & Technology 4 (2) (2021) 103–106

Malaysian Journal of Chemical Engineering & Technology

Journal Homepage: http://myjms.mohe.gov.my/index.php/mjcet

e-ISSN: 2682-8588

Physico-mechanical and water absorption properties of LDPE/cassava starch film

Junaidah Jai*, Siti Fatma Abd Karim, Nurul Asyikin Md Zaki, Rabiatul Adawiyah Abdol Aziz, Farhana Wahet, Nadiah Shafiqah Shaharuddin

School of Chemical Engineering, Collage of Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia

*Corresponding email: junejai@uitm.edu.my

Abstract

Plastic waste is a global crisis, and Malaysia is the 8th worst country worldwide for plastic waste. With this trend, growing market demands for green product have imposed pressure on industries to find an alternative to petroleum-based plastic. Degradable plastic is introduced to overcome this limitation. The present work investigates degradable plastic film of low-density polyethylene incorporated with cassava starch (LDPE-CS). The compounding of the LDPE-CS was prepared via pre-mixing, blending, resin crushing, and film hot pressing. Film thickness, tensile strength, elongation, water absorption, and field test were conducted on the LDPE-CS and commercial LDPE (control). Experimental data of LDPE-CS and commercial LDPE films were evaluated and compared. Thickness of LDPE-CS film was 0.18 mm which was 51% thicker than the control film. Tensile strength and elongation of the LDPE-CS were 7.04 MPa and 5.39%, while control film was 12.77 MPa and 921.5%, respectively. The tensile strength and elongation of the LDPE-SC were significantly lower than the control film, which may be due to the weak interface between LDPE and starch. The water absorption test revealed that the LDPE-CS film absorbed water by 4.8%, which indicates its degradability in the water. The field test shows that the LDPE-CS is biodegradable and comparable with the commercial plant polybag in terms of its capability in planting.

Article Info

https://doi.org/10.24191/mjcet.v4i2.13825

Article history:

Received date: 11 June 2021
Accepted date: 8 October 2021
Published date: 31 October 2021

Keywords:

Degradable plastic
Tapioca starch
Low-density polyethylene
Water absorption
Plant polybag

1.0 Introduction

Low-density polyethylene (LDPE) and high-density polyethylene (HDPE) are widely used in the production of polyethylene plastic films despite of their non-degradable behaviour (Marichelvam et al., 2019). More than 1000 million tons of plastic wastes were predisposed, and the percentage expands. Hence, degradable plastic is introduced to overcome this problem.

Incorporation of starch into the LDPE has increased the degradability of the LDPE film (Datta & Halder, 2018). However, with 30% starch, a reduction by 10–12% of the film tensile strength was observed. Therefore, a good combination of strength and degradability of LDPE/starch film should be tailored made accordingly based on its application. Many researchers focus on the blending/mixture of corn, wheat, rice, and whey starches with low-density polyethylene (LDPE) to produce biodegradable polymers (Kormin et al., 2018). Cassava contains a large amount of starch with amylose and amylopectin as the main compound, hence promotes its potential in the production of LDPE-cassava starch bioplastics (Ojogbo et al., 2020; Wahyuningtyas & Suryanto, 2017;Prachayawarakorn & Pomdage, 2014). However, study on the development of LDPE film incorporated with cassava starch suitable for plant polybag is limited. Hence, this form a basic for this study to perform comparison on physical, mechanical and water absorption properties between LDPE-cassava starch (LDPE-CS) film and commercial LDPE film was conducted. Field study on the LDP-CS film as plant polybag was also performed.

2.0 Methodology

2.1 Material

LDPE was bought from the Lotte Chemical, Titans, Malaysia. Cassava starch (CS) was purchased from

Swee Seng (Sarawak) Sdn. Bhd. Polyethylene grafted maleic anhydride (PEgMA) as compatibilizer was obtained from Sigma Aldrich, USA. Commercial LDPE film was used as a control for the film characterisation. Commercial polybag was used as a control for the field study.

2.2 LDPE-CS film preparation

Dried LDPE and CS at a weight ratio of LDPE:CS (70:30) and 2% wt./wt. PE-g-MA were pre-mixed by manual stirring for 10 min and left for 24 hour at room condition. The mixture was melted, blended in a Banbury Thermo Haake Polylab Internal Mixer at 170 °C and 60 rpm rotation for 10 min. The blended mixture was crushed in a Rexmac Compact Crusher until the size becomes less than 2 mm. Finally, the crushed mixture was hot-pressed using a Cometech Hot Press machine at 130 °C and 1400 psi for 10 min before cooling down to reach room temperature. Finally, the LDPE-CS film was peeled off from the steel plate and ready for further characterisation.

2.3 Thickness and mechanical properties of the film

The samples were cut to a dimension of 100 mm × 25 mm. Thickness of the samples was determined by a micrometre. The mechanical property was determined according to ASTM D882-10 (ASTM.D822-10, 2010) using a Universal Testing Machine (Instron 3382, Norwood, USA), where the films were strained under room temperature condition at a rate of 10 mm/min. The elongation at break was determined from the stress-strain curve at yield point, and the stress was calculated from the force at breaking point divided by the cross-sectional of the test-piece in the undeformed state. Three samples were tested for the thickness and mechanical properties measurement.

2.4 Water absorption

The water absorption (WA) of films was measured according to ASTM D570-63 (Nguyen et al., 2016). All samples were conditioned at 50 ± 1 °C for 24 h and weighed (W0) before being tested. The samples were immersed in distilled water at 25 °C for 24 h before they were removed from the water, drained, and weighed (W_1). After that, they were dried at 50 °C for 24 h and finally weighed again (W_2). Three samples were tested for the water absorption measurement. Water absorption was determined using Eq. (1):

$$\mathrm{WA}(\%) = \left(\frac{W_2 - W_1}{W_0}\right) \times 100\% \qquad (1)$$

2.5 Visual appearance test

Photographic records and light source were used for visual aspect evaluation. The film sample of 10 cm × 15 cm was placed on a white paper written with the word FILM. Then, the camera distance (light source) from the sample was 19 cm. The visual appearance of the covered written text was observed and recorded. Three samples were tested for visual appearance but only one reported in this paper.

2.6 Field study of LDPE-CS as plant polybag

Observation on the potential of LDPE-CS as a plant polybag was done by planting Japanese rose in the LDPE-CS bag and commercial polybag. Only one sample was tested for this study. The plant was daily watered and placed in Malaysian open garden condition without shading for 2 months. Visual observation on the bags and the Japanese rose plant growth was done periodically.

3.0 Results and discussion

3.1 Thickness, tensile and elongation

Table 1 shows thickness, tensile strength and elongation of LDPE-CS and commercial LDPE film. The LDPE-CS is slightly thicker than the commercial LDPE. The standard error of LDPE-CS thickness shows that the hot-pressing techniques manage to produce a film with homogenised thickness. Tensile strength and elongation of LDPE-CS were 7.037 MPa and 5.390%, respectively. These values are significantly lower than the commercial LDPE. These might be due to the weak interface between LDPE and CS; and poor distribution of the starch in the film (Ahamed et al., 1996). Almost similar behaviour was observed by Garg & Jana, (2007) in LDPE-corn starch. They found that the tensile strength of the LDPE was 16.08 MPa and the addition of 7.5% corn starch has reduced the tensile strength by almost 54%, while percentage elongation reduces by 25%. Specific applications might not require high tensile strength, hence the decrease in tensile strength may not be critical.

3.2 Water absorption

Table 2 shows water absorption of LDPE-CS and commercial LDPE film after 24 h of exposure in distilled water. The commercial LDPE reveals its total resistance toward the water, while LDPE-CS uptakes 4.8% water.

Table 1: Thickness, tensile strength, and elongation of LDPE-CS

Properties	Thickness (mm)	Tensile (MPa)	Elongation (%)
LDPE-CS	0.18 ± 0.01	7.04 ± 0.12	5.39 ± 0.42
LDPE commercial	0.09 ± 0.01	12.77 ± 0.46	921.50 ± 0.71
Percent different (%)	51	45	99

Fig. 1: Photograph film of LDPE-SC (top) and commercial LDPE (bottom).

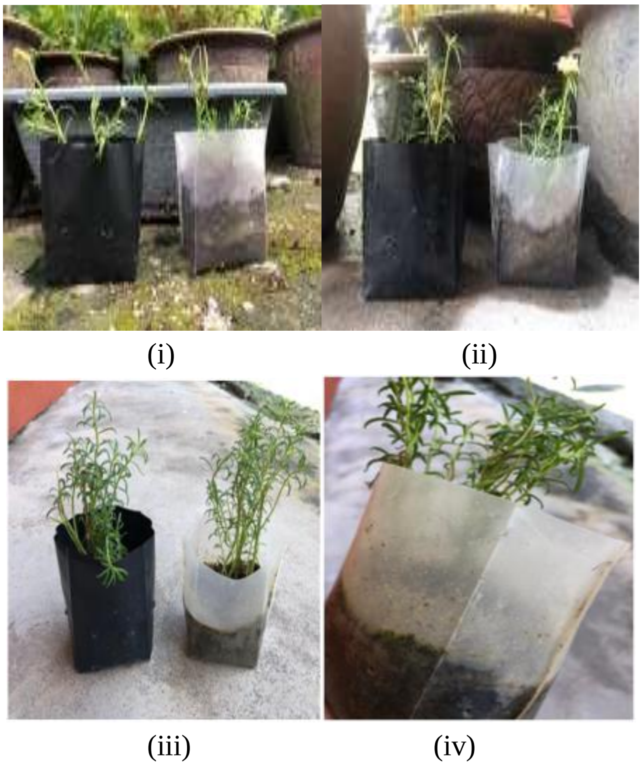

Fig. 2: Photograph of LDPE-SC bag (right-white) and commercial polybag (left-black): (i) day 1, (ii) day 5, (iii) day 60, (iv) small hole spots of LDPE-CS after day 60.

Table 2: Water absorption of LDPE-CS film

Weight (mg)	LDPE commercial (%)	LDPE-CS (%)
W_0	0.207 ± 0.007	0.483 ± 0.009
W_1	0.203 ± 0.003	0.507 ± 0.009
W_2	0.203 ± 0.003	0.483 ± 0.007
WA (%)	0.000	4.828 ± 0.768

Starch is sensitive to water; the hydrogen bond between water and its hydroxyl group creates hydrophilic properties of the LDPE-CS. With the present of microorganisms, this property promotes degradation process of the film (Mao et al., 2016). Hence, water absorption is essential to promote biodegradation of the film.

3.3 Visual appearance

Fig. 1 shows the visual appearance of the LDPE-CS and commercial LDPE. The commercial LDPE had a better visual appearance since the plastic is transparent while the LDPE-CS is translucent plastic. This might be due to the different film formation techniques. The commercial LDPE might be produced through extrusion technique. Extruded films were smooth, bubble free and transparent as reported by Pushpadass et al., (2010). On the other hand, the sheeted films as LDPE-CS are rough and translucent.

3.4 Performance of LDPE-CS as plant polybag

Fig. 2 shows the performance of LDPE-CS as a plant polybag. After 60 days, similar growth of the Japanese rose plant was observed in both polybags. Furthermore, the LDPE-CS bag was in good condition, with small hole spots were observed.

The small hole spots show the degradability of the LDPE-CS bag when exposed to the open garden environment. As discussed in Section 3.2, the hydrophilic property and the microorganism promote the degradability of the bag.

4.0 Conclusions

Incorporating 30% wt./wt. cassava starch and 2% wt./wt. of PEgMA to LDPE produces a biodegradable plastic film with 0.180 ± 0.008 mm thickness, 7.037 ± 0.121 MPa strength, 4.828 ± 0.768 % water absorption and translucent plastic suitable for plant polybag. Exposure of LDPE-CS bag in the open garden for 60 days reveals its potential as a polybag. Further studies on the biodegradability of the polybag in open garden and soil are recommended.

Acknowledgement

The authors would like to acknowledge the School of Chemical Engineering for the technical support and Research Management & Centre (RMC), UiTM Shah Alam for providing financial support under 600-RMC/GPK 5/3 (146/2020)for the financial support.

References

Ahamed, N. T., Singhal, R. S., Kulkarni, P. R., Kale, D. D., & Pal, M. (1996). Studies on Chenopodium quinoa and Amaranthus paniculatas starch as biodegradable fillers in LDPE films. *Carbohydrate Polymers*, *31*(3), 157–160. https://doi.org/10.1016/S0144-8617(96)00019-7

ASTM D882-10, Standard Test Methods for Tensile Properties of Thin Plastic Sheeting, ASTM International, PA, 2010, https://doi.org/10.1520/D0882-10.2

Datta, D., & Halder, G. (2018). Enhancing degradability of plastic waste by dispersing starch into low density polyethylene matrix. *Process Safety and Environmental Protection*, *114*, 143–152. https://doi.org/10.1016/j.psep.2017.12.017

Garg, S., & Jana, A. K. (2007). Studies on the properties and characteristics of starch-LDPE blend films using cross-linked, glycerol modified, cross-linked and glycerol modified starch. *European Polymer Journal*, *43*(9), 3976–3987. https://doi.org/10.1016/j.eurpolymj.2007.06.030

Kormin, S., Kormin, F., & Dalour Hossen Beg, M. (2018). Study of natural weathering exposure on properties of ldpe incorporated with sago starch. *Materials Today: Proceedings*, *5*(10), 21636–21643. https://doi.org/10.1016/j.matpr.2018.07.013

Mao, D., Vi, T., Do, V., Grillet, A., & Ha, H. (2016). International Biodeterioration & Biodegradation Biodegradability of polymer film based on low density polyethylene and cassava starch. *International Biodeterioration & Biodegradation*, *115*, 257–265. https://doi.org/10.1016/j.ibiod.2016.09.004

Marichelvam, M. K., Jawaid, M., & Asim, M. (2019). Corn and rice starch-based bio-plastics as alternative packaging materials. *Fibers*, *7*(4), 1–14. https://doi.org/10.3390/fib7040032

Nguyen, D. M., Do, T. V. V., Grillet, A. C., Ha Thuc, H., & Ha Thuc, C. N. (2016). Biodegradability of polymer film based on low density polyethylene and cassava starch. *International Biodeterioration and Biodegradation*, *115*, 257–265. https://doi.org/10.1016/j.ibiod.2016.09.004

Ojogbo, E., Ogunsona, E. O., & Mekonnen, T. H. (2020). Chemical and physical modifications of starch for renewable polymeric materials. *Materials Today Sustainability*, *7–8*, 100028. https://doi.org/10.1016/j.mtsust.2019.100028

Prachayawarakorn, J., & Pomdage, W. (2014). Effect of carrageenan on properties of biodegradable thermoplastic cassava starch/low-density polyethylene composites reinforced by cotton fibers. *Materials and Design*, *61*, 264–269. https://doi.org/10.1016/j.matdes.2014.04.051

Pushpadass, H. A., Bhandari, P., & Hanna, M. A. (2010). Effects of LDPE and glycerol contents and compounding on the microstructure and properties of starch composite films. *Carbohydrate Polymers*, *82*(4), 1082–1089. https://doi.org/10.1016/j.carbpol.2010.06.032

Wahyuningtyas, N., & Suryanto, H. (2017). Analysis of Biodegradation of Bioplastics Made of Cassava Starch. *Journal of Mechanical Engineering Science and Technology*, *1*(1), 24–31. https://doi.org/10.17977/um016v1i12017p024