Journal of Research in Nanoscience and Nanotechnology

Journal homepage:
http://akademiabaru.com/submit/index.php/jrnn/index
ISSN: 2773-6180

Degradation Behaviour of Arrowroot Fibre (*Maranta Arundinacea*) Reinforced Arrowroot Starch Biocomposite Films

J. Tarique[1], S.M. Sapuan[1,2]*, E.S. Zainudin[1,2], A. Khalina[2,3] , and R.A. Ilyas[4,5]

Advanced Engineering Materials and composites Research Centre (AEMC), Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia [1]
Laboratory of Biocomposite Technology, Institute of Tropical Forest and Forest Products (INTROP), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia [2]
Department of Biological and Agricultural Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia [3]
School of Chemical and Energy Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia [4]
Centre for Advanced Composite Materials (CACM), Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia [5]

* Correspondence: sapuan@upm.edu.my
https://doi.org/10.37934/jrnn.5.1.98102

ABSTRACT

This research is being driven by environmental legislation that requires the consumption and usage of environmentally friendly products. The focus of this research is to develop and characterize thermoplastic arrowroot starch (TPAS) based biocomposite films incorporating arrowroot fibre (AF) at various compositions (0–10 wt.%) using the solution casting method. The biodegradation behaviour of newly developed composite films was examined. The average degradation rates of TPAS and TPAS/AF–10 films were 8 and 9.84%/day, respectively. The soil burial results revealed that the weight loss of TPAS/AF biocomposite films was higher compared to TPAS film. The biocomposite films revealed arrowroot fibre, a novel waste resource that is both eco-friendly and simple to produce. Overall, incorporating arrowroot fibre with TPAS film improves biodegradability, making them more suitable for environmentally friendly food packaging.

Keywords:
Arrowroot fibre; Arrowroot starch; Biocomposite films; Biodegradation behaviour; Soil burial

Received: 12 December 2021 **Revised: 8 April 2022** **Accepted: 10 April 2022** **Published: 17 April 2022**

1. Introduction

Plastics generated from petroleum are one of the most often utilized materials in the packaging industry, which has been causing global environmental concerns for decades [1]. The rise of environmentally hazardous plastic waste has stimulated the development of natural-based, renewable, and biodegradable materials. A variety of fibre reinforcements have recently been used in the context of biopolymers, including potato peel waste, cassava bagasse, and sugar palm [2, 3]. Reinforcing starch matrix and natural fibres has been demonstrated due to their high compatibility because of the formation of a 3D hydrogen bonding structure between starch and fibre components, resulting in improved biocomposite performance (e.g., water permeability, degradation rate and mechanical properties), and thus improving their characteristic as a food packaging material.

The main focus of this research is to investigate how the different arrowroot fibre loadings affect the biocomposite's biodegradability property. It is worth noting that the fibre utilized in this work was not chemically processed or modified, resulting in more environmentally friendly and cost-effective materials.

2. Materials and Methods

2.1 Materials

Arrowroot fibres were extracted from arrowroot tubers obtained from a local market in Kuala Lumpur, Malaysia. Arrowroot fibre in this study has 45.97% cellulose, 30.18% hemicellulose, 2.78% lignin, 4.29% ash and fibre lengths (<300μm). Evergreen Engineering & Resources Sdn. Bhd., Semenyih, Malaysia, supplied the 99% pure glycerol plasticizer.

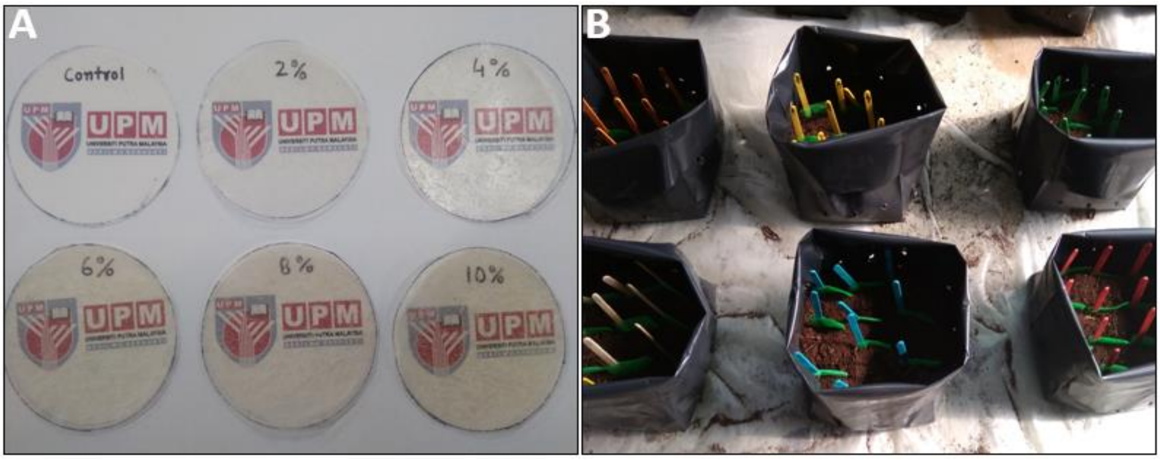

Figure 1: Arrowroot biocomposite films with different loadings (A) and, soil burial setup of degradation experiment (B).

M.M. Kessler came up with the term "bibliographic coupling" in 1963 where two publications have similar references and the strength of the bibliographic coupling increases when there are many references in common [4]. In other terms, bibliographic coupling refers to the overlap in published reference lists. Co-citation is the opposite of bibliographic coupling where two publications are cited by third publication. The visualization of bibliographic coupling document, co-citation of cited reference and cited source were determined in this paper. The summary of methodology used in this paper is visualize through Figure 1.

2.2 Preparation of biocomposite films

The solution casting method was used to produce biopolymer composites. To make the film-forming solution, the arrowroot starch was dispersed in distilled water at a concentration of 5% (w/w, dry basis). Based on a previous study, 1.5 g of glycerol (w/w, dry starch basis) was added to the solution. The arrowroot bagasse fibre was added to the solution as a filler at a range of 0 to 10% by weight. These solutions were heated for 15 minutes in a thermostatic bath (Daihan Scientific, Jalan Buroh, Singapore) at 80±3 °C with steady stirring. To prevent air bubbles from developing, the biopolymer forming solutions were cooled and placed in a vacuum desiccator before casting. Following that, 50 g of each solution was cast in 120 mm diameter Petri dishes to use as a casting surface, resulting in a high surface finish. For dehydration, the cast plates were placed in an airflow oven at 45°C for 24 hours. The dehydrated samples were then conditioned for 24 hours at 25°C before being removed from the plates, as shown in Figure 1. The film samples were stored for a week at 25±3 °C and 52 % relative humidity before being characterized.

2.3 Soil burial

The biodegradation tests were carried out on all samples using the method in previous work 4. Each film sample with a known weight (WI) was buried 100 mm deep in moist soil in a control condition. The weight loss (WL) evaluation was carried out by taking specimens at various times and gently clean them with a soft brush. The samples were then dehydrated for 6 hours at 105 °C before being reweighed (WF). Every couple of days, the degradation analysis was performed on the collected specimens and determined using Equation 1.

$$\text{Weight loss (\%)} = \frac{WI-WF}{WI}\times 100 \quad (1)$$

3. Results and Discussion

The weight losses of control thermoplastic and composite films after 10 days were 72.4, 75.5, 77.8, 78.1, 87.9, and 90.9% for 0, 2, 4, 6, 8, and 10 wt.% fibre loadings, respectively, as shown in Table 1. The C-10 biocomposite sample took 12 days to decompose completely. On the other hand, the biocomposite samples with 2, 4, 6, and 8% fibre loadings lost 73.5, 76.2, 83.3, 87.3, and 93.6%, respectively. The average decomposition rate for the control and C-10 composite films was 8 and 9.84%/day, respectively. The data in Table 1 show that the weight loss of the control film was lower than that of the biocomposite samples. González attributed this to the existence of a link between the water content of the film and the bacterial activity of the soil, where the higher the water content of the film, the higher the bacterial activity within the film [5]. Avérous et al. also obtained consistent results when leafwood fibre was employed as a filler with wheat starch [6]. López et al. obtained consistent results by incorporating fibrous waste from the Pachyrhizus ahipa plant into thermoplastic corn starch films [7]. Hazrati et al. studied Dioscorea hispida/Dioscorea hispida fibre biocomposite films and found that biocomposites with higher fibre concentrations were more degradable than control films [2].

Table 1: Control film weight loss data that was often lower than biocomposites samples.
*C= Composite

Sample /Day	Control	C-2	C-4	C-6	C-8	C-10
2	33.3 ± 1.3	35.3 ± 1.0	39.2 ± 0.6	40.2 ± 0.5	40.6 ± 1.1	40.0 ± 0.8
4	39.0 ± 1.2	40.9 ± 1.2	42.5 ± 1.2	50.6 ± 0.6	52.6 ± 0.9	50.4 ± 0.5
6	51.4 ± 0.4	52.3 ± 2.2	55.1 ± 0.1	60.0 ± 1.0	62.9 ± 0.4	64.2 ± 0.3
8	64.0 ± 0.9	66.7 ± 0.7	67.7 ± 0.7	71.7 ± 0.9	73.2 ± 0.2	78.7 ± 0.9
10	72.4 ± 0.3	75.5 ± 0.5	77.8 ± 0.5	78.1 ± 0.1	87.9 ± 0.8	90.9 ± 0.7
12	73.5 ± 1.3	76.2 ± 0.5	83.3 ± 0.7	87.3 ± 0.3	93.6 ± 0.7	100 ± 0.5

Arrowroot fibre was used to reinforce the arrowroot starch matrix from 0 to 10 wt.% concentration for the preparation of biocomposites via the casting method. In this study, soil burial tests were performed for the unreinforced arrowroot starch film, as well as the bio-composite film sample for 20 days. The biodegradability results revealed that the addition of arrowroot fibre accelerated the biodegradation process because of the hydrophilic nature of the fibre. It also generates new insights on the interactions of different fibre loadings and how they affect film capabilities, which can contribute to the production of biodegradable materials.

Acknowledgments

Authors thank Universiti Putra Malaysia for supporting the research through Geran Putra Berimpak (GPB), UPM.RMC.800-3/3/1/GPB/2020/9694500.

References

1. Tarique, J., Zainudin, E. S., Sapuan, S. M., Ilyas, R. A. & Khalina, A. Physical, Mechanical, and Morphological Performances of Arrowroot (Maranta arundinacea) Fiber Reinforced Arrowroot Starch Biopolymer Composites. *Polymers* (Basel). 14, 388 (2022). doi: 10.3390/polym14030388.
2. Hazrati, K. Z., Sapuan, S. M., Zuhri, M. Y. M. & Jumaidin, R. Preparation and characterization of starch-based biocomposite films reinforced by Dioscorea hispida fibers. *J. Mater. Res. Technol.* 15, 1342–1355 (2021). doi: 10.1016/j.jmrt.2021.09.003
3. Ilyas, R. A., Sapuan, S. M., Ishak, M. R. & Zainudin, E. S. Development and characterization of sugar palm nanocrystalline cellulose reinforced sugar palm starch bionanocomposites. *Carbohydr. Polym.* 202, 186–202 (2018). doi: 10.1016/j.carbpol.2018.09.002
4. Tarique, J., Sapuan, S. M. & Khalina, A. Effect of glycerol plasticizer loading on the physical, mechanical, thermal, and barrier properties of arrowroot (*Maranta arundinacea*) starch biopolymers. *Sci. Rep.* 11, 13900 (2021). doi: 10.1038/s41598-021-93094-y
5. González, A. & Alvarez Igarzabal, C. I. Soy protein - Poly (lactic acid) bilayer films as biodegradable material for active food packaging. *Food Hydrocoll.* 33, 289–296 (2013). doi:10.1016/j.foodhyd.2013.03.010

6. Avérous, L., Fringant, C. & Moro, L. Plasticized starch-cellulose interactions in polysaccharide composites. *Polymer* (Guildf). 42, 6565–6572 (2001). doi: 10.1016/S0032-3861(01)00125-2

7. López, O. V., Versino, F., Villar, M. A. & García, M. A. Agro-industrial residue from starch extraction of Pachyrhizus ahipa as filler of thermoplastic corn starch films. *Carbohydr. Polym.* 134, 324–332 (2015). doi: 10.1016/j.carbpol.2015.07.081