SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879


# Water Absorption and Environmental Properties of Thermoplastic Cassava Starch Reinforced with Durian Skin Fiber

Ridhwan Jumaidin[1,*], Jowel Wong[1], Alia Ruzanna Aziz[2], Meysam Keshavarz[3], Tuan Suhaimi Salleh[4], Rushdan Ahmad Ilyas[5,6], Fudhail Abdul Munir[7], Mastura Mohamad Taha[1], Nadlene Razali[7], Abdul Rafeq Saleman[7], Ahmad Fuad Ab Ghani[1], Nuzaimah Mustafa[1], Nazri Huzaimi Zakaria[1], Mohd Adrinata Shaharuzzaman[7], Syahibudil Ikhwan Abdul Kudus[1], Mohd Yuhazri Yaakob[1]

[1] Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2] Technology Innovation Institute (TII), Advanced Materials Research Centre, PO Box 9639, Masdar City, Abu Dhabi, United Arab Emirates
[3] The Hamlyn Centre, Institute of Global Health Innovation, Imperial College London, Bessemer Building, South Kensington Campus, Exhibition Road, London, SW7 2AZ, United Kingdom
[4] Bahagian Inovasi, Penyelidikan dan Pembangunan Kejuruteraan, Pusat Kecemerlangan Kejuruteraan dan Teknologi JKR (CREaTE), Jalan Kemus Simpang Ampat, 78000 Alor Gajah, Melaka, Malaysia
[5] School of Chemical and Energy Engineering, Faculty of Engineering, Universiti Teknologi Malaysia (UTM), Johor Bahru 81310, Malaysia
[6] Centre for Advanced Composite Materials (CACM), Universiti Teknologi Malaysia (UTM), Johor Bahru 81310, Malaysia
[7] Fakulti Kejuruteraan Mekanikal, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

**ARTICLE INFO**

***Article history:***
Received 12 March 2022
Received in revised form 20 May 2022
Accepted 25 May 2022
Available online 19 June 2022

***Keywords:***
Thermoplastic starch; cogon grass; water absorption

**ABSTRACT**

In recent, the efforts to reduce environmental pollution by developing biodegradable material has received wide interest. The aim of this paper is to investigate the effect of durian skin fiber (DSF) on the properties of thermoplastic cassava starch (TPCS) matrix as the biodegradable material. The composites were prepared by using hot press technique to convert the starch into thermoplastic starch polymer. The effects of incorporating different amount of DSF (0-50 wt.%) on the matrix was evaluated using several testings, i.e., water absorptions, water solubility, thickness swelling, moisture content, biodegradation analysis and density measurement. The results show that incorporation of DSF has reduce the water absorption characteristic of the material. Thickness swelling of the sample were increase following the addition of DSF into the TPCS matrix, indicating improve environmentally friendly properties. Water solubility of the composites showed a decreasing trend with increasing DSF content. The morphology of the samples shows adhesion of fiber and matrix which indicates good compatibility between this component. Meanwhile, there is no apparent changes on the density of the composites following the incorporation of fiber. Overall, this finding shows that DSF has potential to improve the functional characteristics of TPCS matrix as alternative green material.

* *Corresponding author.*
*E-mail address: ridhwan@utem.edu.my*

https://doi.org/10.37934/arfmts.96.2.115121

## 1. Introduction

There is no doubt that the synthetic polymers do play an important part in this modern era in applications such as packaging products, household appliances, and automotive components. The wide application of synthetic polymers is mainly due to its light weight, low cost and water resistivity properties. However, under normal circumstances, synthetic polymers have an insignificant decay rate. Improper disposal of these material poses a threat in contributing to environmental pollution by its accumulation in landfills. Hence, to overcome this problem, a more biodegradable material is to be an alternate to synthetic polymers.

Starch has been a promising alternative to synthetic polymers due to its availability, low cost and biodegradable properties [1,2]. It is a macromolecule consisting of α-D-glucose units, that comes in two forms: amylose and amylopectin [3]. Amylose is predominantly linear and slightly branched while amylopectin is highly branched. Starch can be formed into a thermoplastic starch (TPS) with the presence of heat, shear, and a plasticizer. However, TPS does show weak mechanical properties and lower dimensional stability when compared to synthetic polymer. Different type of starches made from potato, cassava, and corn are some the commonly used starch for the formation of TPS as seen in past studies [4-6]. To improve the properties of TPS, reinforcements are to be incorporated into the TPS. From past studies, improvements of TPS are made incorporating various type of natural fibers.

Polymer composites is an engineering material which utilize the effect of matrix-reinforcement interaction to improve the characteristics of the polymer material. Various types of reinforcement have been developed for this application and natural fiber reinforcement is one of the most promising for more sustainable option of materials. The performance of natural fiber and its reinforcement has been reported in the previous studies [7–11].

Durian, also known as '*Durio zibethinus*' is a popular seasonal fruit in South East Asian countries, known for its pyramidal spikes on the husks. Only 50-65% of durians are to be consumed, while the rest of the durian is considered as wastes [12]. Durian wastes includes the stem, skin, and seed of the fruit. Disposal of these natural wastes can result in a negative impact to the environment. Hence, durian skin can be a source of natural fiber for reinforcement in TPS. Despite the low value of this natural waste, durian skin possesses high potential as reinforcement due to the strong structure of this part which mainly contain of cellulose. Even though this natural resource possesses high potential as reinforcement, however, there are very few studies conducted on the performance of this material as reinforcement and none has been found on using durian skin fiber as reinforcement for thermoplastic starch/beeswax matrix.

Therefore, in this study, we are incorporating natural materials such as cassava starch and durian skin fibers to develop a biodegradable material in efforts to be an alternate to synthetic materials. This paper focuses on the density, morphological properties, water affinity and the environmental properties of thermoplastic starch reinforced with a variation amount (0, 10, 20, 30, 40, 50 wt.%) of durian skin fiber (TPCS/DSF).

## 2. Materials and Methodology

### *2.1 Materials*

Food grade cassava starch was procured from Antik Sempurna Sdn Bhd, Malaysia. Glycerol used as a plasticizer was purchased from QReC Chemical. Beeswax was purchased from Sigma Aldrich chemical. Durian skin were collected from local market in Melaka, Malaysia.

### *2.2 Sample Fabrication*

Development of TPCS and DSF bio composite is carried out with TPCS as the matrix while DSF as the reinforcement in the composite. Durian skin collected from the stalls undergo a process called water retting for the extraction of DSF. Once the fibers are collected, it is dried before being used as reinforcement of TPCS. Ratio of cassava starch to glycerol is kept constant at 100:30 (wt. %). Both components are mixed inside a high-speed mixer (1200 rpm) until a homogenous mixture is obtained. The mixture is then hot pressed at a temperature of 155°C, with pressure of 30 tons for 1 hour. TPCS of different fiber loading (0, 10, 20, 30, 40, 50 wt.%) is developed (Table 1). Samples were placed in the desiccator immediately to avoid unwanted moisture adsorption until further testing.

**Table 1**
Composition of the sample prepared

| Fiber content (wt.%) | Designation |
|---|---|
| 0 | TPCS/DSF0 |
| 10 | TPCS/DSF10 |
| 20 | TPCS/DSF20 |
| 30 | TPCS/DSF30 |
| 40 | TPCS/DSF40 |
| 50 | TPCS/DSF50 |

### *2.3 Moisture Content*

To determine the moisture content of the samples. The initial mass of the samples is taken before it is placed into the oven for 24 hours at 105°C. The final weight of the samples after drying is recorded. Percentage of the change of weight of the samples are calculated as in Eq. (1). $W_f$ represents the final weight and $W_i$ represents the initial weight of the samples.

$$Moisture\ Content\ (\%) = \frac{Wi - Wf}{Wi} \times 100\% \quad (1)$$

### *2.4 Water Adsorption*

Water adsorption testing of the samples were carried out with ASTM 570-98 as reference. Samples are first dried in the oven for 24 hours at 105°C, then weighed to obtain its initial mass. The samples are then placed into distilled water at room temperature. The masses of the samples after submerged in distilled is recorded after 30 minutes and 2 hours were recorded. Weight difference of the samples corresponds to the amount of water adsorbed. Percentage of the change of weight of the samples are calculated as in Eq. (2). $W_f$ represents the final weight and $W_i$ represents the initial weight of the samples.

$$Water\ adsorption\ (\%) = \frac{Wf - Wi}{Wi} \times 100\% \quad (2)$$

### *2.5 Thickness Swelling*

Testing for the thickness swelling of the samples is carried out with using ASTM D570-98 as reference. Samples are first dried in the oven for 24 hours at 105°C, the initial thickness of the samples are taken using a Mitutoyo digital calipers. The samples are then placed into distilled water at room temperature. The final thickness of the samples is recorded after submerged in distilled

water for 30 minutes. Percentage of the thickness swelling of the samples is calculated in Eq. (3). $T_f$ represents the final weight and $T_i$ represents the initial weight of the samples.

$$Thickness\ swelling\ (\%) = \frac{Tf - Ti}{Ti} \times 100\% \quad (3)$$

## 3. Result and Discussion

### *3.1 Moisture Content*

Figure 1 shows the moisture content of the TPCS samples. There are significant changes in the moisture content of the samples with increasing fiber content up to 40 wt.%. TPCS/DSF0 samples shows the highest moisture content of 6.00 wt.%, followed by 4.89 wt.%, 3.39wt.%, 2.33 wt.% and 1.72 wt.% for TPCS/DSF10, TPCS/DSF20, TPCS/DSF30, TPCS/DSF40. The decreasing in the trend of moisture content is attributed by the greater adhesion between the reinforcement and matrix [13]. However, TPCS/DSF50 samples show increase in the moisture content up to 4.00 wt.% could be due to the insufficient fiber-matrix wetting in the samples [13]. This would result in the interaction between moisture and carboxyl groups in the fiber [14].

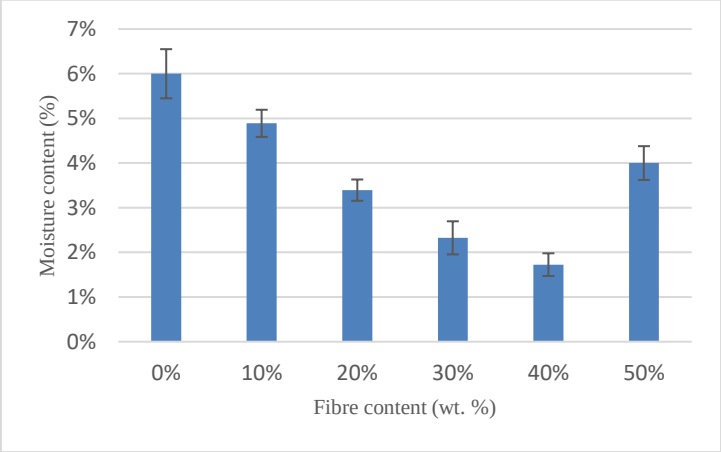


**Fig. 1.** Moisture content of TPCS samples

### *3.2 Water Adsorption*

Water adsorption of TPS is an important factor in investigating the water affinity of the material when applied in a realistic environment. Figure 2 shows the water adsorption of the TPCS samples after two periods, 30 minutes, and 2 hours. After a longer period, the TPCS samples shows higher water intake. This could be caused by the hydrophilic properties of both the starch matrix and the fiber reinforcement [15]. However, TPCS/DSF40 shows the lowest water adsorption rate in both time periods. This is caused by the great adhesion between the starch matrix and the fiber [16]. The increase in the water intake of TPCS/DSF50 could be resulted by the insufficient fiber-matrix wetting [13].

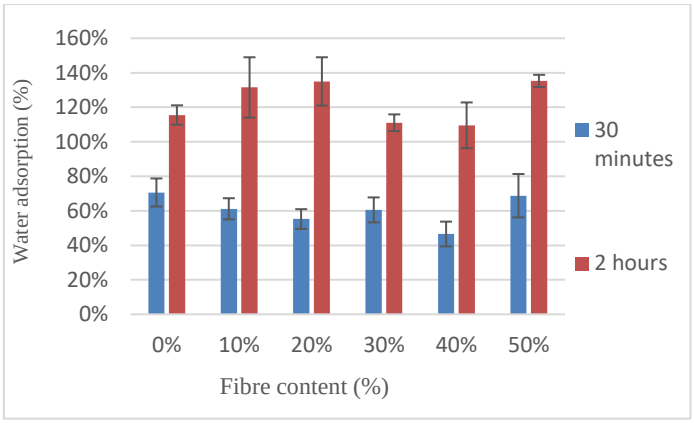


**Fig. 2.** Water adsorption of TPCS samples

### *3.3 Thickness Swelling*

Thickness swelling of a TPCS is an important parameter in the structural stability of the material when exposed to water. Figure 3 shows the fluctuation of the thickness swelling of TPCS samples. This fluctuation could be caused by the non-homogenous structure in the samples [15,17]. However, TPCS/DSF50 shows the lowest thickness swelling rate compared to other samples reinforced with DSF. This could be caused by the high crystallinity of the fibers and the higher affinity of water molecules to react with starch [17,18].

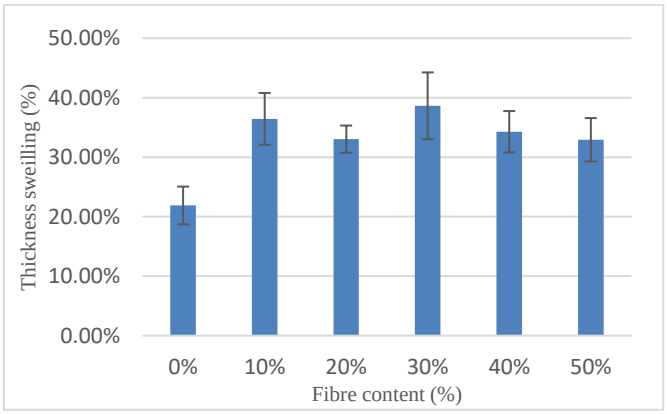


**Fig. 3.** Thickness swelling of TPCS samples

## 4. Conclusion

A biodegradable material can be successfully developed with TPCS and DSF through dry mixing and hot pressed at the specified parameters. It is seen that there is a decrement of the moisture content and water adsorption of TPCS with the incorporation of DSF. This indicates the improved resistance to moisture with the incorporation of DSF. However, this finding was accompanied with increase in the thickness swelling of the samples. Nevertheless, this study shows that the addition of DSF able to improve the moisture resistance and water affinity behavior of the samples. Overall, this new material is a potential environmentally friendly material which could be used as alternative to the petroleum based plastic.

**Acknowledgement**
The authors would like to express sincere gratitude to Universiti Teknikal Malaysia Melaka and Ministry of Higher Education Malaysia for the financial support provided through research grant RACER/2019/ FTKMP-CARE/F00413, the conference proceeding was supported by publication incentive grant JURNAL/FTK/2018/Q00004.

## References

[1] Ilyas, R. A., S. M. Sapuan, Rushdan Ibrahim, Hairul Abral, M. R. Ishak, E. S. Zainudin, A. Atiqah et al. "Thermal, biodegradability and water barrier properties of bio-nanocomposites based on plasticised sugar palm starch and nanofibrillated celluloses from sugar palm fibres." *Journal of Biobased Materials and Bioenergy* 14, no. 2 (2020): 234-248. https://doi.org/10.1166/jbmb.2020.1951

[2] Diyana, Z. N., R. Jumaidin, Mohd Zulkefli Selamat, Ihwan Ghazali, Norliza Julmohammad, Nurul Huda, and R. A. Ilyas. "Physical properties of thermoplastic starch derived from natural resources and its blends: a review." *Polymers* 13, no. 9 (2021): 1396. https://doi.org/10.3390/polym13091396

[3] Prachayawarakorn, Jutarat, Sudarat Chaiwatyothin, Suwat Mueangta, and Areeya Hanchana. "Effect of jute and kapok fibers on properties of thermoplastic cassava starch composites." *Materials & Design* 47 (2013): 309-315. https://doi.org/10.1016/j.matdes.2012.12.012

[4] Eterigho, Elizabeth J., T. S. Farrow, E. Ejejigbe Silver, and Gideon O. Daniel. "Study of the Physical Properties and Biodegradability of Potato-Starch Based Plastics." In *Proceedings of the World Congress on Engineering and Computer Science*, vol. 2. 2017.

[5] Kamaruddin, Zatil Hafila, Ridhwan Jumaidin, Rushdan Ahmad Ilyas, Mohd Zulkefli Selamat, Roziela Hanim Alamjuri, and Fahmi Asyadi Md Yusof. "Biocomposite of Cassava Starch-Cymbopogan Citratus Fibre: Mechanical, Thermal and Biodegradation Properties." *Polymers* 14, no. 3 (2022): 514. https://doi.org/10.3390/polym14030514

[6] Zakaria, Nazri Huzaimi, Ridhwan Jumaidin, Mohd Adrinata Shaharuzaman, Mohd Rody Mohamad Zin, and Fudhail Abdul Munir. "Mechanical and physical properties of thermoplastic corn starch." *Jurnal Teknologi* 83, no. 5 (2021): 119-127. https://doi.org/10.11113/jurnalteknologi.v83.16576

[7] Ismail, Fatiha, Nur Eliyanti Ali Othman, Noorshamsiana Abdul Wahab, and Astimar Abdul Aziz. "The Effect of Chemical and High Pressure Homogenization Treatment Conditions on the Morphology of Nanocellulose." *Journal of Advanced Research in Applied Mechanics* 93, no. 1 (2022): 1-7.

[8] Bakhori, Siti Nadia Mohd, Siti Nur Fatin Zuikafly, Fauzan Ahmad, and Mohamad Zaki Hassan. "Tensile properties for MWCNT filled jute-Epoxy composites." *Journal of Advanced Research in Applied Mechanics* 31, no. 1 (2017): 16-21.

[9] Aziz, Annis Nazirah Abdul, and Roszilah Hamid. "Mechanical properties and impact resistance of hybrid kenaf and coir fibre reinforced concrete." *Journal of Advanced Research in Applied Mechanics* 47, no. 1 (2018): 1-10.

[10] Loha, X. H., Mohd Ahadlin Mohd Daud, and M. Zulkefli Selamat. "A Study on Fibre Length and Composition of Kenaf-Polypropylene (K-PP) Composite for Automobile Interior Parts." *Journal of Advanced Research in Materials Science* 1, no. 1 (2014): 22-27.

[11] Yee, Koh Chai, Azwan Iskandar Azmi, Wan Azani Mustafa, Aiman Akmal Abdul Nasir, and Tan Chye Lih. "Effect of Notch and Notch Size on the Flexural Performance of Flax Fibre Composites." *Journal of Advanced Research in Applied Mechanics* 52, no. 1 (2018): 1-7.

[12] Manshor, M. R., H. Anuar, MN Nur Aimi, MI Ahmad Fitrie, WB Wan Nazri, S. M. Sapuan, Y. A. El-Shekeil, and M. U. Wahit. "Mechanical, thermal and morphological properties of durian skin fibre reinforced PLA biocomposites." *Materials & Design* 59 (2014): 279-286. https://doi.org/10.1016/j.matdes.2014.02.062

[13] Humairah, A. R. N., A. Zuraida, S. Norshahida, and A. W. N. Izwah. "Effect of kenaf fibre on starch based biopolymer composite." *Advances in Environmental Biology* (2014): 765-770.

[14] Guleria, Ashish, Amar Singh Singha, and Raj K. Rana. "Mechanical, thermal, morphological, and biodegradable studies of okra cellulosic fiber reinforced starch-based biocomposites." *Advances in Polymer Technology* 37, no. 1 (2018): 104-112. https://doi.org/10.1002/adv.21646

[15] Jumaidin, Ridhwan, Zulhelmi Asyul Sutan Saidi, Rushdan Ahmad Ilyas, Mohd Nazri Ahmad, Mohammad Khalid Wahid, Mohd Yuhazri Yaakob, Nurul Ain Maidin, Mohd Hidayat Ab Rahman, and Mohd Hairizal Osman. "Characteristics of cogon grass fibre reinforced thermoplastic cassava starch biocomposite: Water absorption and physical properties." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 62, no. 1 (2019): 43-52.

[16] Sarifuddin, Norshahida, Hanafi Ismail, and Zuraida Ahmad. "Effect of fiber loading on properties of thermoplastic sago starch/kenaf core fiber biocomposites." *BioResources* 7, no. 3 (2012): 4294-4306.

[17] Ramírez, María Guadalupe Lomelí, Kestur G. Satyanarayana, Setsuo Iwakiri, Graciela Bolzon de Muniz, Valcineide

Tanobe, and Thais Sydenstricker Flores-Sahagun. "Study of the properties of biocomposites. Part I. Cassava starch-green coir fibers from Brazil." *Carbohydrate Polymers* 86, no. 4 (2011): 1712-1722. https://doi.org/10.1016/j.carbpol.2011.07.002

[18] Santana, Jamille Santos, Jamile Marques do Rosário, Cícero Cardoso Pola, Caio Gomide Otoni, Nilda de Fátima FerreiraSoares, Geany Peruch Camilloto, and Renato Souza Cruz. "Cassava starch-based nanocomposites reinforced with cellulose nanofibers extracted from sisal." *Journal of Applied Polymer Science* 134, no. 12 (2017). https://doi.org/10.1002/app.44637