Advances in Environmental Biology, 8(3) Special 2014, Pages: 765-769

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/aeb.html

Effect of Kenaf Fibre on Starch Based Biopolymer Composite

[1]A.R.N. Humairah, [1]A. Zuraida, [2]S. Norshahida and [1]A.W.N. Izwah

[1]Department of Manufacturing & Materials Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, Jalan Gombak, 53100, Kuala Lumpur, Malaysia.
[2]Cluster for Polymer Composite, School of Materials and Mineral Resources Engineering, University Science Malaysia, Engineering Campus, 14300, Nibong Tebal, Penang, Malaysia.

ARTICLE INFO

Article history:
Received 14 Feb 2014
Received in revised form 24 February 2014
Accepted 29 March 2014
Available online 14 April 2014

Key words:
Sago starch, Kenaf Bast Fibre, Composite, Reinforcement, Plasticizer

ABSTRACT

The properties of a thermoplastic starch were enhanced with the reinforcement of kenaf fibre (*Hibiscus canabinus*). The development of the starch-kenaf biopolymer composite was motivated to improve the polymer biocompatibility, biodegradability as well as to reduce the dependency of synthetic polymers within plastic materials. The investigated biocomposite was prepared through extrusion technique and later compression moulded at varying fibre content of 0, 5, 10, 20 and 30 wt. %, based on total dry weight. The thermoplastic sago starch mixture was fixed at glycerol/starch weight ratio of 30/70. The effect of the fibre incorporation was evaluated by tensile test, morphological analysis and moisture content. Tensile test resulted in an improved strength and modulus with the increase of fibre content until it reached an optimum at 20 wt. % of fibre loading. The evidence from morphological analysis showed the occurrence of good wetting between the polymer matrix and fibre which is one of the factors that provides tensile improvement. Reduction of moisture content was achieved with higher fibre content with the lowest rate measured of 13.8%.

To Cite This Article: A.R.N. Humairah, A. Zuraida, S. Norshahida, A.W.N. Izwah., Effect of Kenaf Fibre on Starch Based Biopolymer Composite. ***Adv. Environ. Biol., 8(3),*** *765-769, 2014*

INTRODUCTION

The convenience and versatility of polymer plastics in our life is indisputable. They are, however, create environmental pressure. The pressure arises from the enlarging of plastic waste disposal problems, pollutions and depletion of petroleum resource. Thus, recent attention has focused on the development of environmental friendly polymer derived from natural materials, widely called as biopolymer. These biopolymers, such as polycaprolactone, polyhydroxyalkanoates and polylactic acid[1], are biodegradable but are not economically viable compared to petroleum-based plastics and with limited commercial usage [1].

Starch is one of the renewable resources that can be converted into biodegradable thermoplastic or bioplastic with the addition of a plasticizer [2]. Starch has polysaccharide groups containing linear structure of amylose and highly-branched amylopectin. These microstructures facilitate the conversion of starch to a thermoplastic. Starch is easy to gelatinize, highly viscous, non-toxic, inexpensive, biocompatible and widely available throughout the year. Sources of starch are available from potato, rice, tapioca, corn, wheat, barley and others. In addition, sago palm (*Metroxylon* spp.) which is present in South East Asia produces rich source of starch [3,4]. Remarkably, a single palm can produce more than 200 kg of starch [4].

Although the thermoplastic starch exhibits similar physical characteristics to synthetic polymers [5], unfortunately, the low mechanical properties and water resistance of the thermoplastic starch requires it to be modified or reinforced with other materials. Modifications of thermoplastic starch have been reported by other researchers through blending with synthetic polymers [6,7], natural polymers [8,9,10], cross-linking [11], nanoclay fillers [12,13,14] and fibres [15,16].

In this present work, natural fibre was introduced to yield a lighter and inexpensive yet durable composite. Kenaf (*Hibiscus canabinus*) is an annual crop growing in warm-season and tropical areas and grows to a height of 2.7 to 3.6 meters [17]. It consists of 60 – 80% cellulose which is responsible for the strength and stiffness while hemicellulose involves in moisture absorption and thermal degradation of the fibre [18.19].

Due to its good fibre quality, superior tensile and flexural strength [20] kenaf is made into ropes and canvas and able to be used as reinforcement for polymer matrix composites [18]. It is proven, for example, that this

Corresponding Author: A. Zuraida, Department of Manufacturing & Materials Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, Jalan Gombak, 53100, Kuala Lumpur, Malaysia
E-mail: zuraidaa@iium.edu.my

excellent fibre resulted in higher tensile and flexural properties compared to other natural fibre based composites [21.22].

Therefore, a development of environmental friendly biopolymer composite from sago starch (*Metroxylon rottb*.) reinforced with kenaf fibre is highlighted in this work. The effect of various kenaf fibre content towards tensile properties, morphological as well as moisture content of the biocomposite will be discussed.

MATERIALS AND METHODS

Materials:

Sago starch powder (25% amylose) was purchased from Hup Seng Heng Sdn. Bhd., Malaysia while glycerol (99.5 % purity) was obtained from Merck Chemicals, Malaysia and used as received. Kenaf bast fibre was supplied by Institute of Tropical Forestry and Forest Products (INTROP), Malaysia.

Fabrication process:

Starch was dried in a vacuum oven at 80 ºC for 8 hours while the unmodified fibre was cut into a length of approximately 400 µm. The glycerol/starch weight ratio was 30/70 before adding the fibre at 0, 5, 10, 20 and 30 wt. % and mechanically stirred for 5 min. The mixture was then stored overnight at ambient temperature of 20 - 25 ºC (R. H. 60 ± 5 ºC). The mixture was melt-blended with a twin screw extruder (Thermo HAAKE Rheomix 600) at 130 °C, 100 rpm. Then, the extrudate was granulated before being compression moulded in an electrical heated hydraulic press. The preheating process was done at 150 °C for 6 min and compression at 150 °C for 3 min. The compression moulded sheet with dimensions of 150 x 150 x 2 mm was cold pressed for 2 min and later was kept in sealable polyethylene bag for further used.

Tensile test:

Tensile test was conducted on dumbbell shaped samples by using Universal Testing Machine (Instron 3366) at a crosshead speed of 5 mm/min. Test was done in accordance with ASTM D 412, which was performed in ambient temperature with 5 test specimens for each batch.

Surface morphology:

Scanning Electron Microscope (SEM) (Model Quanta 200 MK2) examined the morphology of the biocomposite at 5 kV and 50/60 Hz. Surface of the samples was sputter-coated with gold-palladium prior to SEM observation.

Moisture content:

Samples of dimensions 10 x 10 x 2 mm were tested for the moisture content test. The specimens for moisture content were initially weighed, dried in circulating oven at 80 °C for 24 hours and reweighed. Five samples were tested for each test to obtain the average values. The moisture content was calculated using Equation (1) as follows:

$$\text{Moisture content (\%)} = \frac{W_f - W_o}{W_o} \times 100\% \quad (1)$$

where W_f and W_o are the weights of the sample after drying and initial weight of the sample, respectively.

RESULTS AND DISCUSSION

Tensile test:

Figure 1 represents the tensile strength and modulus of the starch-kenaf based biocomposite where both strength and modulus increase with fibre incorporation. An addition of 5 wt. % of kenaf fibre into the thermoplastic starch matrix caused 300% of improvement in tensile strength. The modulus was also increased as addition of fillers to the polymer controlled the movement of its chain and thus increased the stiffness. This improvement indicated the effectiveness of the reinforcing materials. Maximum tensile properties were achieved until 20 wt. % of fibre content. The enhancement of tensile properties was due to the substitution of new hydrogen bonding between the hydroxyl groups in starch and kenaf fibre during the composite processing [23].A reduction of tensile properties, however, occurred at higher fibre loading of 30 wt. %. Therefore, it can be postulated that the optimum tensile properties were signified by the volume of reinforcement used in the composites. At higher fibre content, inadequate fibre-matrix wetting occurred that led to poor adhesion between both constituents [24]. It is associated with fibre agglomeration which caused more fibre-fibre interaction due to the fact that fibre tends to form hydrogen bonds with each other [25]. Thus, it prevented uniform stress to transfer from the matrix to the reinforcement, resulting in reduced tensile properties.

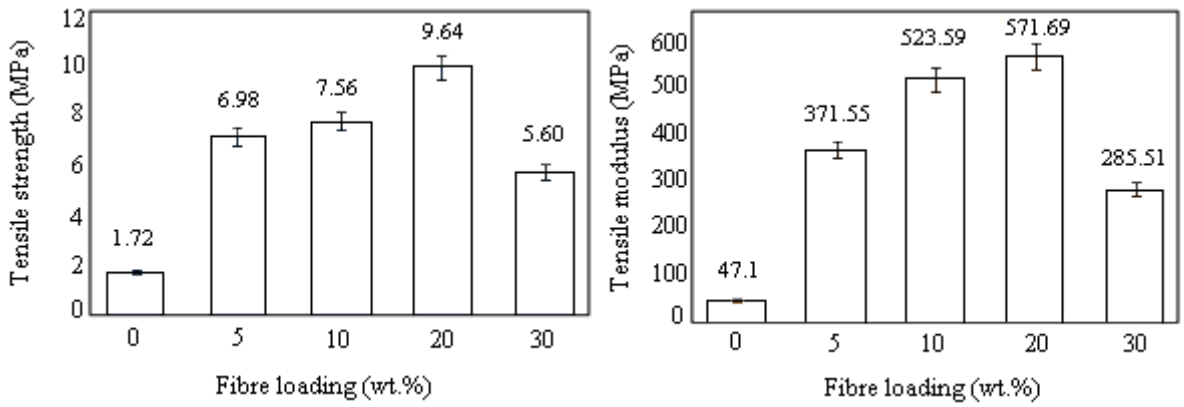

Fig. 1: Tensile properties of the starch-kenaf biopolymer composite.

Surface morphology:

The fractured surface of the tensile samples was analyzed by SEM and the micrographs are shown in Figure 2 at 500x magnification. The micrographs represent a significant difference in the surface condition between the unreinforced and reinforced composite. Unreinforced thermoplastic starch has a smooth and homogeneous surface as well as no interphase separation representing miscibility between the starch and plasticizer (Figure 2a). There is no starch granule observed, indicating the processing parameters were adequate to fully gelatinized the starch. On the other hand, Figure 2b and 2c show the reinforced composite with kenaf fibre have rough surfaces, little fibre tearing and wetting of fibre with the starch matrix. This clarifies that there was an adequate interfacial adhesion [16,26] among the starch and fibre due to similar polarity [27] between both constituents which lead to an improved strength as compared to the unreinforced composite. A good fibre-matrix binding leads to a resistant interface and also reinforcing the matrix [28]. At higher filler content, however, there was insufficient filling of the matrix that caused voids, more tearing of fibre and little fibre wetting. This explained the reduction of tensile properties as indicated in Figure 1.

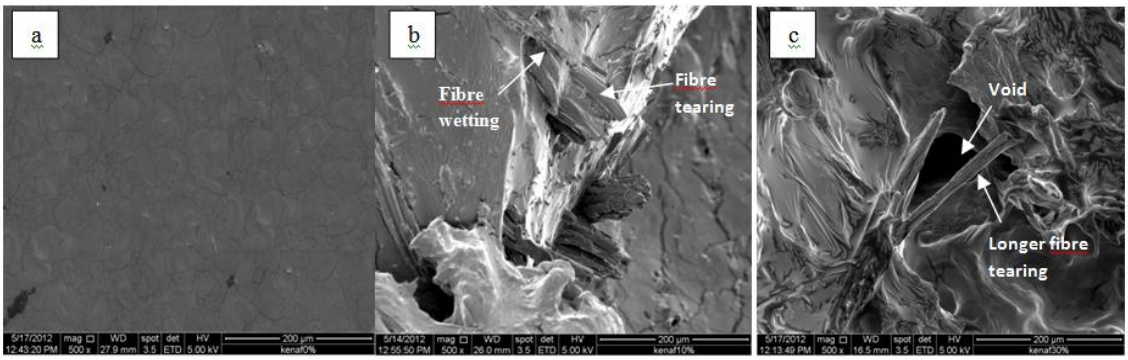

Fig. 2: SEM images of starch reinforced kenaf fibre biocomposite at (a) 0 wt.%, (b) 10 wt.% and (c) 30 wt.% of kenaf fibre content.

Moisture content:

Investigation on moisture content for natural fibre reinforced composites is essential especially for outdoor application or usage in high humidity environment. Figure 3 evaluates the moisture content of the polymer composite at different fibre loading. The moisture content decreased with the increment of fibre loading where the unreinforced composite yielded 16.5 % moisture content while at 30 wt.% of fibre loading, the moisture content was the lowest (13.8 %). Thus, the unreinforced thermoplastic absorbed more moisture compared to the reinforced composite. When a good interfacial adhesion and binding exists between the reinforcement and matrix, there is minimum chance of hydroxyl groups of the matrix coming into contact with water molecules from the surrounding environment [16] as suggested from the SEM results. In addition, it also shows that the amount of fibre incorporated plays a role in the composite moisture content. It can be postulated that greater hydrophilic behavior of the starch than the kenaf fibre had caused higher moisture absorption in the unreinforced sample [29].

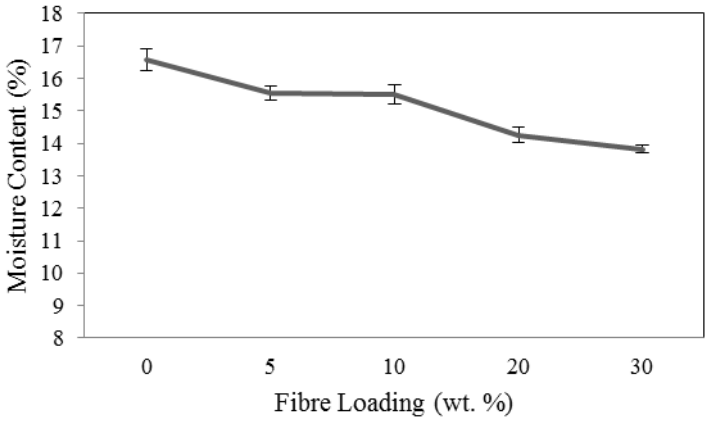

Fig. 3: The moisture content of starch-kenaf biocomposite.

Conclusions:

A biopolymer composite from sago starch reinforced with kenaf bast fibre was fabricated by extrusion process and compression moulded. The mechanical, morphological and physical properties of starch based biopolymer composite reinforced with kenaf fibre were studied. The study showed that the effect of kenaf fibre content in the thermoplastic starch improved the tensile properties until 20 wt.% of fibre loading. Furthermore, analysis from SEM showed an adhesion and good binding among the starch and fibre which lead to an improved strength. Finally, the unreinforced thermoplastic absorbed more moisture compared to the reinforced composite and addition of higher fibre reduced the moisture content.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to Institute of Tropical Forestry and Forest Products (INTROP) for supplying the finest quality of kenaf bast fibre.

REFERENCES

[1] Avella, M., J.J. De Vlieger, M.E. Errico, S. Fischer, P. Vacca, M.G. Volpe, 2005. Biodegradable starch/clay nanocomposite films for food packaging applications. Food Chemistry, 93: 467-474.
[2] Zuraida, A., A.R.N. Humairah, A.W.N. Izwah, Z.S. Naqiah, 2012. The study of glycerol plasticized thermoplastic sago starch. Advance Materials Research, 576: 289-292.
[3] Awg-Adeni, D.S., S.A. Aziz, K. Bujang, M.A. Hassan, 2010. Bioconversion of sago residue into value added products. African Journal of Biotechnology, 9(14): 2016-2021.
[4] Malviya, R., P. Srivastava, A. Pandurangan, M. Bansal, P.K. Sharma, 2010. A brief review on thermo-rheological properties of starch obtained from *Metroxylon sagu*. World Applied Science Journal, 9(5): 553-560.
[5] Fazilah, A., M. Maizura, A.A. Karim, K. Bhupinder, B. Rajeev, U. Uhumporn, S.H. Chew, 2011. Physical and mechanical properties of sago starch-alginate films incorporated with calcium chloride. International Food Resource Journal, 18(3): 1027-1033.
[6] Averous, L., N. Boquillon, 2004. Biocomposites based on plasticized starch: Thermal and mechanical behaviours. Carbohydrate Polymer, 56: 111-122.
[7] Sharma, N., L.P. Chang, Y.L. Chu, H. Ismail, U.S. Ishiaku, Z.A.M. Ishak, 2001. A study on the effect of pro-oxidant on the thermooxidative degradation behavior of sago starch filled polyethylene. Polymer Degradation and Stability, 71: 381-393.
[8] Shen, X.L., M.J. Wu, Y.H. Chen, G.H. Zhao, 2010. Antimicrobial and physical properties of sweet potato starch films incorporated with potassium sorbate or chitosan. Food Hydrocolloids, 24: 285-290.
[9] Shishonok, M.V., V.V. Litvyak, E.A. Murshko, E.V. Grinyuk, L.I. Sal'nivok, L.P. Roginets, L.P. Krul, 2007. Structure and properties of electron-beam irradiated potato starch. High Energy Chemistry, 41: 425-429
[10] Zhou, Y.G., L.J. Wang, D. Li, P.Y. Yan, Y.B. Li, J. Shi, X.D. Chen, Z.H. Mao, 2009. Effect of sucrose on dynamic mechanical characteristics of maize and potato starch films. Carbohydrate Polymers, 76: 239-243.
[11] Reddy, N., Y. Yang, 2010. Citric acid cross-linking of starch films. Food Chemistry, 118: 702-711.

[12] Cyras, V.P., L.B. Manfredi, M.T. Ton-That, A. Vazquez, 2008. Physical and mechanical properties of thermoplastic starch/montmorillonite nanocomposite films. Carbohydrate Polymers, 73: 55-63.
[13] Kampeerapappun, P., D. Aht-Ong, D. Pentrakoon, K. Srikulkit, 2007. Preparation of cassava starch/montmorillonite composite film. Carbohydrate Polymers, 67: 155-163.
[14] Souza, A.C., R. Benze, E.S. Ferao, C. Ditchfield, A.C.V. Coelho, C.C. Tadini, 2012. Cassava starch biodegradable films: influence of glycerol and clay nanoparticles content on tensile and barrier properties and glass transition temperature. Food Science and Technology, 46: 110-117.
[15] Ma, X., J. Yu, J.F. Kennedy, 2005. Studies on the properties of natural fibre-reinforced thermoplastic starch composites. Carbohydrate Polymers, 62: 19-24.
[16] Yunos, M.Z.B., W.A.W.A. Rahman, 2011. Effect of glycerol on performance rice straw/starch based polymer. Journal of Applied Sciences, 11(13): 2456-2459.
[17] Khalil, H.P.S.A., A.F.I. Yusra, A.H. Bhat, M. Jawaid, 2010. Cell wall ultrastructure, anatomy, lignin distribution and chemical composition of Malaysian cultivated kenaf fibre. Industrial Crop Products, 31: 113-121.
[18] Akil, H.M., M.F. Omar, A.A.M. Mazuki, S. Safiee, Z.A.M. Ishak, A.A. Bakar, 2011. Kenaf fibre reinforced composites: A review. Materials & Design, 32: 4107-4121.
[19] Khalil, H.P.S.A., N.L. Suraya, 2011. Anhydride modification of cultivated kenaf bast fibers: morphological, spectroscopic and thermal studies. Bioresources, 6(2): 1122-1135.
[20] Edeerozey, A.M., H. M. Akil, A.B. Azhar, M.I.Z. Ariffin, 2007. Chemical modification of kenaf fibre. Materials Letter, 61(10): 2023-2025.
[21] Lee, S.H., S. Wang, 2006. Biodegradable polymers/bamboo fibre biocomposites with bio-based coupling agent. Composite Part A: Applied Science Manufacturing, 37: 80-91.
[22] Oksman, K., M. Skrifvars, J.F. Selin, 2003. Natural fibre as reinforcement in poly(lactid) acid. Composite Science Technology, 63: 1317-24.
[23] Zuraida, A., Y. Yusliza, H. Anuar, R.M.K. Muhaimin, 2012. The effect of water and citric acid on sago starch bio-plastics. International Food Research Journal, 19(2): 715-719.
[24] Kalaprasad, G., K. Joseph, S. Thomas, C. Pavithran, 1997. Theoretical modeling of tensile properties of short sisal fibre-reinforced low-density polyethylene composites. Journal of Materials Science, 32: 4261-4267.
[25] Liu, W., A.K. Mohanty, P. Askeland, L.T. Drzal, M. Misra, 2004. Influence of fibre surface treatment on properties of Indian grass fibre reinforced soy protein based biocomposites. Polymer, 45: 7589-7596.
[26] Deka, H., M. Misra, A. Mohanty, 2013. Renewable resource based "all green composites" from kenaf biofibre and poly(furfuryl alcohol) bioresin. Industrial Crop Products, 41: 94-101.
[27] Prachayawarakorn, J., P. Sangnitidej, P. Boonpasith, 2010. Properties of thermoplastic rice starch composites reinforced by cotton fibre or low-density polyethylene. Carbohydrate Polymer, 81(2): 425-433.
[28] Fowler, P.A., J.M. Hughes, R.M. Elias, 2006. Biocomposites: Technology, environmental credentials and market forces. Journal of Science and Food Agriculture, 86: 1781-1789.
[29] Averous, L., C. Fringant, 2001. Association between plasticized starch and polyesters: Processing and performance of injected biodegradable systems. Polymer Engineering Science, 40: 727-734.