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Research paper

Effect of PVA on Mechanical Properties of Tapioca Starch Reinforced Coconut Fiber Biopolymer Composite

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Abstract

The usage of polyvinyl alcohol (PVA) in polymer matrix has been explored for natural fiber composites to improve mechanical properties of the polymer. The PVA-modified tapioca starch was then used to produce coconut fiber composites. The study used 5 wt%, 10 wt% and 15 wt% of PVA in the tapioca starch. PVA-modified tapioca starch reinforced coconut fiber biopolymer composite was then proceeded with mechanical tests namely tensile test and impact test. All the specimens were tested in accordance to ASTM Standard; D3039/D3039M-08 and ASTM D256 for tensile properties and impact properties respectively. The results from the experiment showed that the tensile strength increased with increasing contents of PVA. PVA 15 wt% showed the highest tensile strength of 3.5 MPa. Another PVA contents of 5 wt% and 10 wt% showed tensile strength of 2.753 MPa and 3.064 MPa respectively. Apart from that, the result from impact test also showed that the impact energy increased with increasing content of PVA. PVA 15 wt% showed the highest impact energy of 1.054 J. Another PVA contents of 5 wt% and 10 wt% showed impact energy of 0.584 J and 0.872 J respectively.

Keywords: *Biocomposite; biopolymer; coconut fiber; PVA; tapioca starch*

1. Introduction

Based on the mechanics of composite materials, the word composite in composite materials signifies that two or more materials are combined on a macroscopic scale to form a useful material [1]. In short, composite materials are formed by combining materials together in order to form a better structure. The evolution of composite material started since 4000 B.C when people laminated writing materials from papyrus plant, 1300 B.C with the used of straw bricks by Egyptians and Mesopotamian, 1200 A.D during the invention of composite bows by Mongols. The advantages of forming composite materials can contribute to improve properties such as strength, stiffness, corrosion resistance and fatigue life. The specific and unusual properties of composites are for the high technology applications such as bioengineering, automotive, aerospace and transportation sector [2-3].

The applications of petroleum-based products are commonly used in this country since it is easy to get raw materials. Petroleum based products provided good strength, and they are also known as synthetic polymers. The current issue is petroleum takes hundreds of years to degrade and the petroleum resource will deplete over time. If the waste is not managed well, it can become an environmental pollution. In order to sustain our environment, the usage of non-renewable resources should be reduced for benefits of the future generation. Therefore, the needs to depend on renewable resources such as biocomposite materials from nature is very critical. The biodegradability of biocomposite is to support the waste disposal management and facilitate the environmental issue. In recent years, the drastic increment of plastics disposal due to the increasing global demand of non-renewable polymer products has resulted in the environmental destruction. Therefore, new environmental legislation and consumer pressure have encouraged the implementation of biodegradable natural fiber reinforced polymer composites as a substitution to the petroleum based polymers as well as the conventional non-renewable polymer composites. Biocomposites help to utilize plant starch as biopolymer at low cost and is widely available. Starch from corn, rice, wheat or potatoes can be used to produce polymers and it is an inexpensive and abundant base material. The project involves with the application of tapioca starch that acts as a matrix. Tapioca starch can help to reduce the usage of petroleum base polymer. Biocomposite can utilize natural fiber that are easily available and abundant in Malaysia. For this project, it concerns the coconut fiber as the reinforcement in the biocomposite. Compared to conventional fiber (synthetic fiber) which is glass fiber or carbon fiber, coconut fiber costs less expensive than those materials.

Coconut fiber or also known as known as coir fiber is one of the natural fibers which is attractive due to their low cost and their mechanical properties. The coconut fiber is obtained and extracted from the husk of coconut fruits. The husk contains coconut fiber and corky tissue which is also known as pith [4]. Coconut fiber can be classified into two groups which are brown fiber and white fiber. Brown fiber can be extracted or obtained from matured coconuts and mostly used in engineering since it has strong abrasion resistance, thick and strong. While white fiber is extracted from immatured coconuts and it is finer, smoother and weaker compared to the brown fiber.

The coconut fiber is not only used to make mats, caulking boats and ropes. It can also be used to make automotive paneling interior [5]. The automotive industry really needs the use of the green composite for the industry since the industry needs to face with some challenges which are to create low polluting vehicle and fuel efficient. All of these problems are the driving force for the industry to produce lighter vehicles using fiber reinforced composite. The natural fiber which has lightweight properties will help the automotive industry the most. The use of synthetic fiber such as glass fiber and carbon fiber will give some impacts such as difficulties to dispose and to recycle.

In recent years, there has been an increase in natural fiber reinforced with PVA-starch modified polymer. The resources of compositions come from natural resource. Basically, PVA added into polymer matrix which is starch from natural resource is to improve the properties of matrix. PVA is a polymer of great interest because of its many desirable characteristics; high mechanical properties, biodegradability, excellent gas barrier properties and transparency [6]. Creation of blended systems with other polymers is a promising way of modification of strength-deformation properties of PVA. PVA is a water soluble synthetic polymer which is a colourless and is well known as a biodegradable synthetic polymer [7]. It is produced through the hydrolysis of polyvinyl acetate. It is nontoxic, strong, durable, highly crystalline, water-soluble polymer and has good film-forming and high hydrophilic properties. PVA has high tensile strength and flexibility, good oxygen and barrier properties, excellent emulsifying and adhesive properties [8]. PVA has excellent barrier properties, and are used in fibers, films and adhesive agents widely. Chemical crosslinking is a highly versatile method to create and modify polymers, where properties can be improved such as mechanical, thermal and chemical stability [9][10].

In this paper, PVA was used to modify the tapioca starch as the binder of a biocomposite material. The PVA-modified tapioca starch was then used in the fabrication of coconut fiber reinforced tapioca starch composites. The effect of PVA contents of 5wt%, 10wt% and 15wt% on mechanical properties of tensile and impact properties were investigated. The PVA functions as a modifier to improve the properties of tapioca starch.

2. Materials and methods

2.1. Materials

The polyvinyl alcohol (PVA) and glycerol used for this study were supplied by Ever Gainful Sdn Bhd. Coconut fiber (coir) used as natural fiber was supplied by Kota Kemuning Nursery & Landscaping Sdn Bhd and Mydin Mart Padang Jawa, Shah Alam, supplied tapioca starch that was used as a natural polymer. The moulds were fabricated at the Faculty of Mechanical Engineering, UiTM Shah Alam.

2.2. Sample Preparation

First, a series of PVA contents (addition of 5 wt%, 10 wt% and 15 wt%) were measured to a desired measurement by using digital weighing scale provided by the laboratory. Tapioca starch was mixed with hot water and stirred until it dissolved completely. By using hot water, it can help to dissolve starch easily. Glycerol was added into tapioca starch mixture in the beaker. Then, it was stirred until completely dissolved. PVA was added into the mixture and stirred again. Next, the coconut fiber was poured into the mixture in the beaker. The mould was completely coated by a freecoat solution to avoid the specimen sticking with the mould. The mixture was poured into a mould (250 mm x 250 mm) and placed in the oven at a temperature of 90º C for a 24 hours duration. Finally, the specimen was left to cool in room temperature for another 24 hours. The images of the processes are shown in Fig. 1.

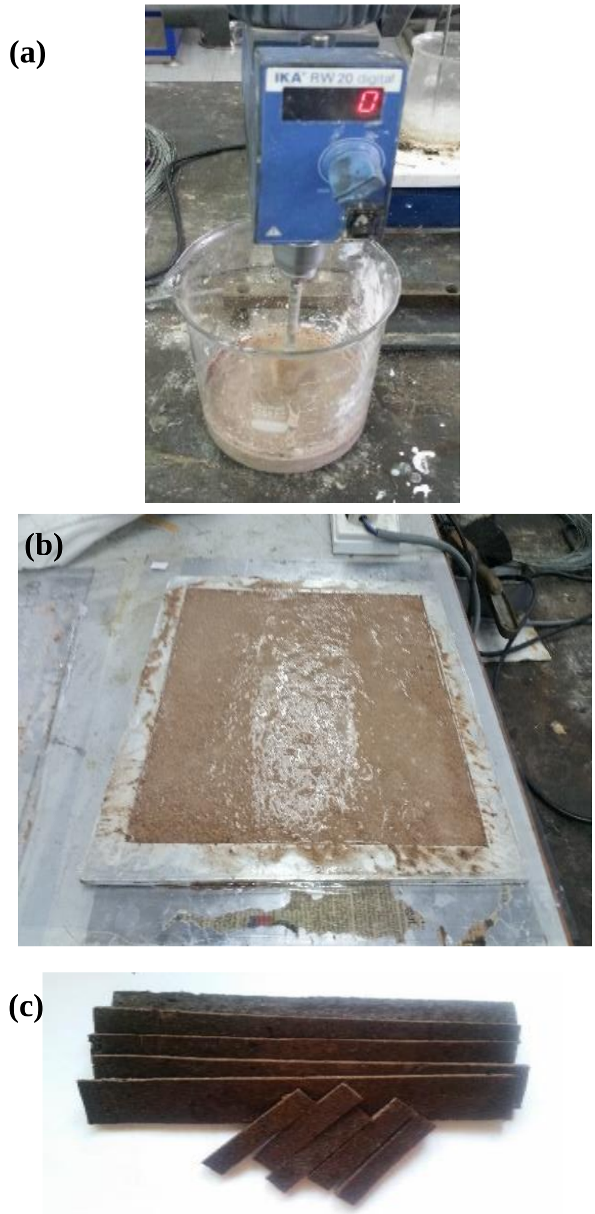

Fig. 1: (a) Stirring of the solution. **(**b) Fabrication of biocomposite by solution casting technique. (c) The prepared specimen ready to proceed with mechanical tests.

2.3 Tensile Test

The tensile strength of PVA-modified tapioca starch reinforced coconut fiber composites were determined according to ASTM D3039/D3039M-08. The rectangular specimens with dimension of 200mm x25mm x 5mm were used in this test. The Instron 3382 Universal Testing Machine was used to perform the tensile test.

2.4 Impact Test

Izod Impact Test is in accordance to ASTM D256 Notched Izod Impact by using Izod Charpy Machine at Low Energy of 30 J. This single point test measures a material resistance to impact from a swinging pendulum. The rectangular specimens with dimension of 60 mm x 10 mm x 5 mm were used in this impact test. At least, fives samples were prepared for each impact test to determine the properties.

2.5 Biodegradability Test

Biodegradability is to measure self-degradability of the biocomposite due to the reaction of the biomaterials towards microorganism in the ground. The test was done according to the ASTM G130 standard. The initial weight of the biocomposite was recorded before burial. Then the weight after burial was recorded at certain days.

2.6 SEM Images

Scanning Electron Microscopy (SEM) analysis was conducted by using the Hitachi SU3500 model. The incorporation of the PVA increases the strength of the biocomposite. Subsequently, the SEM images observation was done to study the failure surface that could give supportive opinion on the mechanism of the strengthening biocomposite.

3. Results and discussions

3.1. Tensile Strength

The tensile properties of tapioca starch reinforced coconut fiber biopolymer composites with different weight percentages of PVA are shown in Fig. 2. It shows that that tensile strength of specimen increase with the increase in the PVA contents. It reveals that the tensile strength for tapioca starch reinforced coconut fiber biopolymer composites are influenced by adding the amount of PVA.

Based on Fig. 2, as the PVA contents increase, tensile stress slightly increases from 2.753 MPa to 3.5 MPa. Since the PVA provides good adhesion properties, the bonding between matrix composition and reinforcement requires high tensile stress before experiencing fracture. This can be supported by the result that shows addition of PVA 15wt% gives higher tensile stress of 3.5 MPa. PVA ensures matrix to transfer stresses to the fibers by adhesion across the fiber-matrix interface when the composite is under load, thus avoid any catastrophic propagation of cracks and subsequent failure of composites [11]. PVA having higher numbers of hydroxyl groups forming good intermolecular bonding between matrix and fiber, incurs higher strength and better mechanical properties [12]. PVA is an inert and organic adhesive that is highly used to obtain high density products due to its role as a good adhesion agent. PVA was chosen due to its homogeneity in functional groups, linearity and solubility in water [13] [14].

The tensile result also align with the previous research that state increasing the PVA content will increase the tensile strength of the composite system. The addition of PVA improved the tensile strength due to its character as a water-soluble synthetic polymer with excellent film-forming and emulsifying capability [6]. Among the synthetic polymers, PVA is a promising carrier that has relatively good tensile stress, impact strength, high water affinity, wear resistance, good biocompatibility, and good adhesion [7]. In addition, PVA is one of the best options to be blended with starch based on the previous research that offered excellent mechanical properties [8]. Therefore, the mechanical property increased by the addition of PVA.

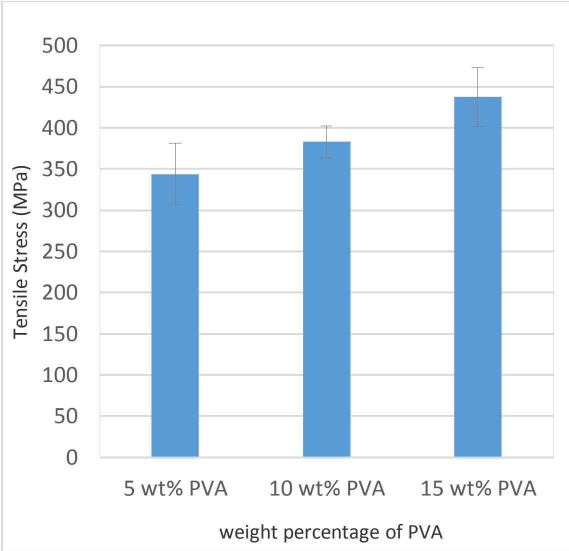

Fig. 2: Tensile strength of tapioca starch reinforced coconut fiber biopolymer composite with different PVA contents.

3.2. Impact Strength

Impact strength of tapioca starch reinforced coconut fiber biopolymer composites with different weight percentages of PVA is shown in Fig. 3. The result shows that the impact strength for tapioca starch reinforced coconut fiber biopolymer composites is influenced by the amount of PVA added.

Impact strength is analogous to the stiffness and toughness of materials because it is defined as the ability of a material to absorb energy when impacted. The higher the impact energy, the tougher the materials. In other word, toughness is resistant to impact load. Common techniques to measure energy absorption are by Charpy Impact Test or Izod Impact Test. From Fig. 3, it shows that the highest impact energy is 1.054 J with PVA 15 wt% content. This is the greatest value compared to 0.584 J and 0.872 J for PVA 5 wt% and PVA 10 wt% respectively. Addition of PVA contribute to the strong and good adhesion properties in matrix-fiber composition in the composite system. The enhancement in impact strength is described throughout the matrix having good dispersion with coconut fiber, which helps to increase the interaction or adhesion at the matrix/coconut fiber interface. Therefore, as the PVA contents increase, the material becomes tougher resulting in improvement of impact strength.

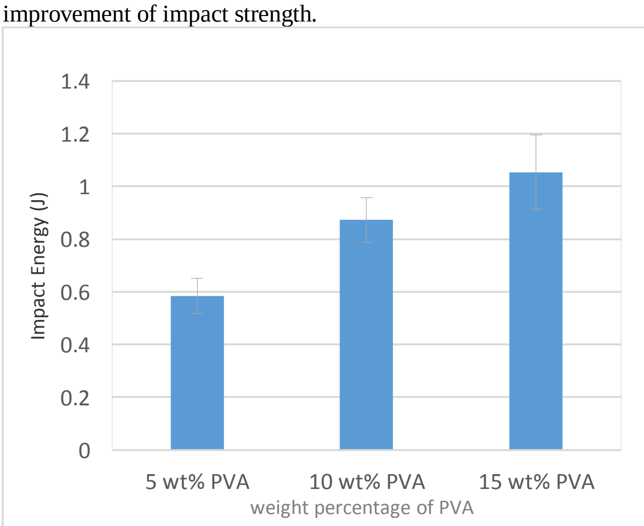

Fig. 3: Impact strength of tapioca starch reinforced coconut fiber biopolymer composite with different PVA contents.

3.3. Biodegradability

Biodegradable test shows that all biocomposites with different PVA contents decompose naturally. Fig. 4 shows the effect of PVA contents toward the weight loss percentage when the samples were buried in soil for 20 days. As shown in the figure, the percentage of weight loss increases as the day of biodegradation increases. The weight loss was recorded every 5 days until day 20. Every 5 days there are weight loss in each of the sample. This situation shows that the biocomposite can be degraded by time due to several factors which are factor of absorption of water, microbial population and the starch contain in the composite. Weight loss increases with increment of degradation time. Both starch and PVA consists of hydroxyl (-OH) groups that react with microorganism. The longer the biodegradation time, more natural biochemical reaction occurs to decompose the blended starch-PVA.

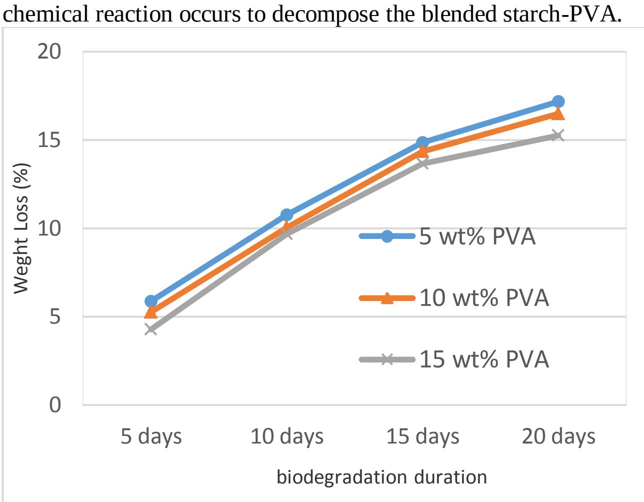

Fig. 4: Biodegradation of tapioca starch reinforced coconut fiber biopolymer composite with different PVA contents.

3.4. SEM images

SEM image analysis were done to study the morphology of the fractured surface of biocomposite containing different amount of PVA addition. PVA plays an important role in improving the performance of tapioca starch reinforced coconut fiber biopolymer composites. Fig. 5 (a) shows the image of fiber pull-out on the fracture surface of lower PVA content of 5 wt%. The fiber pull-out created a hole on the opposite surface. Fiber pull-out indicates a weak interfacial bonding between matrix and fiber thus decreases the tensile strength and impact strength of the biocomposite as revealed in the previous discussion. Meanwhile fiber breakage as shown in the Fig. 5 (b) for higher PVA content of 15 wt% is indication of strong adhesion of matrix and fiber resulting in increment of tensile and impact strength as discussed earlier.

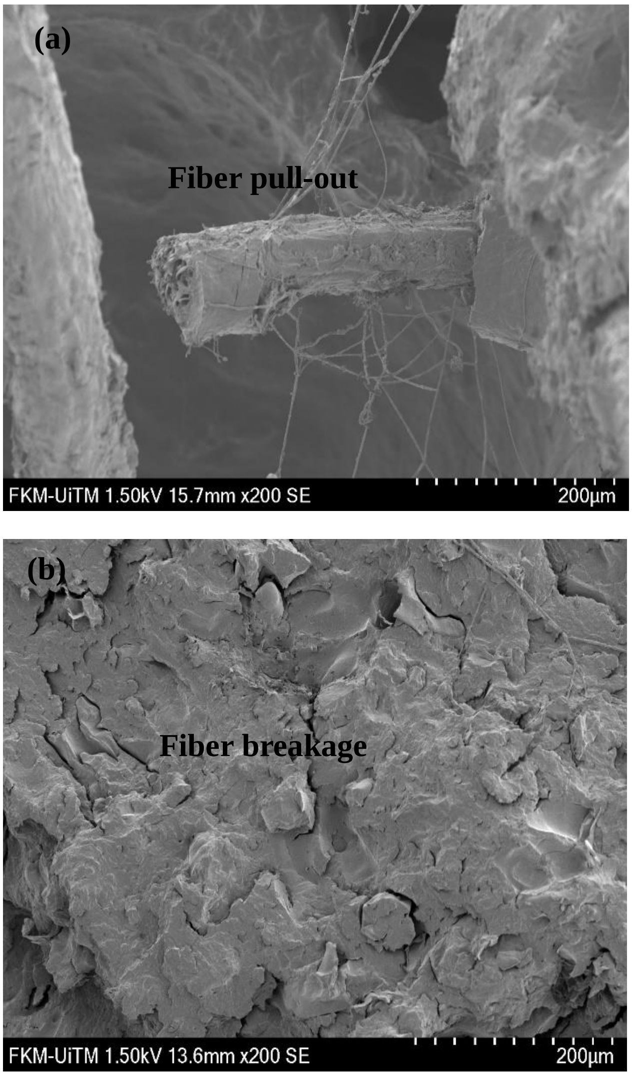

Fig. 5: Fracture surface of tapioca starch reinforced coconut fiber biopolymer composite with (a) 5 wt % PVA and (b) 15 wt % PVA.

4. Conclusion

The study carried out has successfully met the goals of this project, namely, to fabricate biocomposite materials and to study the mechanical properties of PVA-modified tapioca starch reinforced coconut fiber biopolymer composites. The effect of PVA on tensile and impact properties of tapioca starch reinforced coconut fiber biopolymer composites was studied. The tensile strength increase with the increasing contents of PVA. In conclusion, the addition of PVA contents increases the tensile and impact properties of tapioca starch reinforced coconut fiber biopolymer composites due to the improvement in fiber-matrix interfacial bonding.

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