Degradation Characteristics of SPF/SPS Biocomposites

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Abstract

In this work, sugar palm fibres (SPF) were used as a biodegradable reinforcement. SPF were incorporated into sugar palm starch (SPS) plasticised with glycerol using the compression molding process. Then the SPS and SPF/SPS biocomposites were submitted to biodegradation by means of soil burial experiments. The environmental effect on the SPS and SPF/SPS biocomposites were a loss in tensile strength of 78.09% and 53.67%, respectively, at the end of 72 hrs of the weathering testing period. The biodegradation test shows that SPS degrades very quickly and loses 63.58% of its weight at the end of 72 hrs compared to the SPF/SPS biocomposites.

Key words: *sugar palm fibres, sugar palm starch, biodegradable, environmental.*

Introduction

Nowadays more researchers are developing fully biodegradable composites, so-called 'green' composites or biocomposites which are composed of natural fibres and natural matrices [1]. Oksman et al. [2] reported a work on manufacturing of PLA/flax biocomposites, while Van den Oever et al. [3] examined different types of agrofibres such as ramie, flax and cotton, reinforced into PLA to form fully biodegradable composites. Gindl and Keckes [4] investigated biocomposites of cellulose acetate butyrate reinforced with cellulose. Meanwhile Bledzki and Jaszkiewicz [5] investigated the mechanical performance of biocomposites based on PLA and PHBV reinforced with natural fibres. Other researchers have studied the properties of natural fibre reinforced thermoplastic starch composites [6 - 9].

Recently sugar palm fibre has become the most popular reinforcement material among researchers due to its high durability and resistance to seawater [10]. The inner part of the sugar palm stem contains starch which can be developed as a biomatrix [11]. What is of interest in these finding is that we develop new biodegradable biocomposites where the matrix (SPS) and fibre (SPF) are derived from the same natural source i.e. sugar palm tree.

SPF/SPS biocomposites can be applied in the automotive and packaging industries. In order to study the durability of biocomposites, their degradation and environmental characteristics must be thoroughly evaluated. So far, no information on the environmental effect and biodegradability of SPF/SPS biocomposites has been reported in the literature. To this end, new biocomposites based on SPS and SPF were developed and the main objective of the present study was to characterise the environmental effect and biodegradation properties of the biocomposites. These basic data are necessary for the design and use of the resultant biocomposites.

Materials and method

Preparation of materials

The sugar palm fibre (SPF) was collected at Jempol, Negeri Sembilan. All of the fibres were ground and screened using a Fritsch pulverisette mill in order to have a uniform size of the fibres i.e. 2 mm. For the extraction of sugar palm starch (SPS), firstly woody fibres and starch powder are obtained from the interior part of the trunk. Then this mixture (woody fibres and starch powder) was washed out to obtain the starch, which was kept in the open air for a moment and dried in an air circulating oven at 120 °C for 24 hrs.

Fabrication of SPF/SPS biocomposites

Sugar palm starch (SPS) and glycerol of 70/30 wt% were mixed using a mechanical stirrer for 30 min. Subsequently the sugar palm fibres were added with the above mixture and stirred for 20 min. The mixture was cast in an iron die and kept for pre-curing at room temperature (28 °C) for 24 hrs. Finally the SPF/SPS biocomposite was cured by hot pressing in a Carver hydraulic hot press at 130 °C for 30 min at a load of 10 tons. The final biocomposite was obtained in the form of plate with dimensions of 150 × 150 × 0.3 cm and labelled as SPF/SPS

Weathering test

To find out the environmental effect on the biocomposites, samples were treated in an Xenon arc weathering chamber at the Plastics Technology Group, SIRIM Berhad, Malaysia. The weathering test was performed according to ASTM G155. The technical parameters used in the weathering test are shown in ***Table 1***. After the weathering test a tensile test was performed using an Instron 3365 tensile tester, according to ASTM D638 and loss of tensile test was recorded. Specimens of tensile were cut

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by using vertical saw with dimensions of 150 mm (L) × 25 mm (W) × 3 mm (T) and five specimens were tested with cross-head speed of 5 mm/min.

Biodegradability test

Biodegradability was determined by measuring the weight loss of the bio-composite buried in compost soil under moisture controlled conditions. Triplicate specimens (30 × 10 mm) of each SPS and SPF/SPS were buried 100 mm beneath the surface of the soil, which was regularly moistened with distilled water. Each specimen was dug out of the compost soil after being buried for 24, 48 and 72 h, respectively, and then washed with water and dried to a constant weight at 60 °C in a vacuum oven. The weight loss was then determined using the equation below:

$$\text{Weight loss (\%)} = \frac{W_0 - W_t}{W_0} \times 100 \quad (1)$$

where, W_0 = weight before being buried, W_t = weight after being buried.

Surface morphology

Surface characteristics of the SPS and SPF/SPS specimens were examined by a Dino-Lite Digital Microscope (ANMO Electronics Corporation, Hsinchu, Taiwan) in order to observe the degradation phenomenon after the biodegradability test.

Results and discussion

Environmental effect of biocomposites

Figure 1 shows the loss of tensile strength of both the SPS matrix and SPF/SPS biocomposite due to the weathering test. It was found that fibre reinforcement occurred and mechanical properties of the SPF/SPS biocomposites had increased significantly [12]. However, after 72 h the tensile strength loss of the SPS matrix was 78.09% (from 2.42 MPa to 0.53 MPa), while for the SPF/SPS biocomposite it was 53.67% (from 5.31 MPa to 2.46 MPa). This can be attributed to the degradation of both starch (SPS) and natural fibre (SPF) by UV radiation [13, 14]. However, it is clear from the study that SPF degrades slowly and prevents the biocomposite from environmental degradation. Shubhra et al. [15] claimed that in the presence of oxygen, UV causes oxidative degradation of the polymer and it can change the morphology of the polymeric material by means of chemical crosslinking or chain scission.

Table 1. *Technical parameter of weathering test.*

Black panel temperature, °C	Humidity (RH), %	Radiation strength	Filtering system	Exposure duration, h
28	82	0.55 W/m^2 @ 340 nm	BSL/Quartz filter glass	72

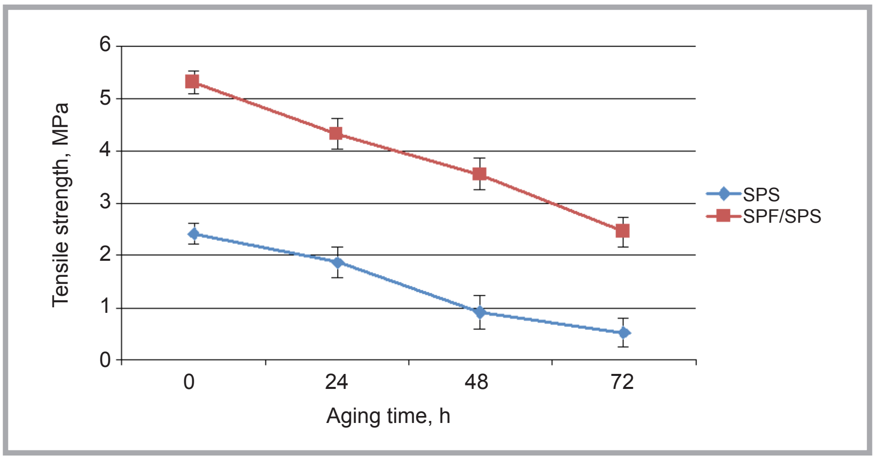

Figure 1. *Tensile strength of SPS and SPF/SPS biocomposites.*

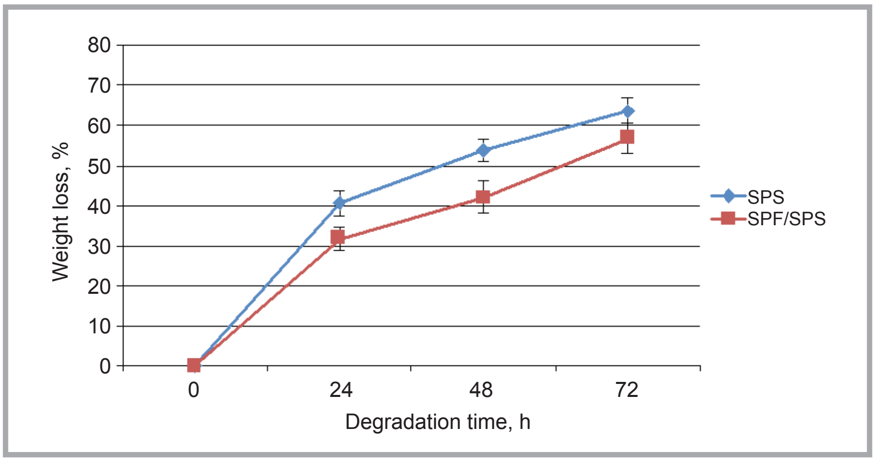

Figure 2. *Weight loss in % of SPS and SPF/SPS biocomposites.*

Biodegradation of biocomposites

The weight loss of the SPS and SPF/SPS biocomposites after biodegradation testing is shown in ***Figure 2***. At the end of 72 h, the SPS had lost 63.58% weight, while the SPF/SPS biocomposite had shed 56.73% weight. The SPS was totally degraded after 1 week, meanwhile for the SPF/SPS biocomposite it took 10 days to completely degrade. The weight loss for the SPS matrix was higher compared to the SPF/SPS biocomposite for all successive degradation tests, which can be attributed to the fact that SPS absorbs more water, making it more prone to microorganism attack [16]. These microorganisms, in the form of bacteria and fungi, access the SPS in the presence of a water medium; the result implies that the samples with higher starch contents would exhibit potential for better biodegradability [17]. The water sorption for SPS was about 24%, while for SPF/SPS biocomposites it was 17.8 %, 15.6 % and 15% (corresponding to SPF10, SPF20 and SPF30), respectively, which could be attributed to the hydrophilic behaviour of SPS [12]. Biodegradation is the break down of materials by the action of microorganisms. Once in contact with the biodegradable polymer, the microorganisms produce enzymes that break down the polymers in progressive smaller segments which have lower average molecular weights. Since starch consists of macromolecule amylose and amylopectin, the enzymes reacted to the starch and degraded to a small molecule of glucose and sucrose. Thus favoring the material's degradation in the environment [18].

Surface morphology

Figure 3 (see page 98) shows the degradation of the SPS and SPF/SPS bio-

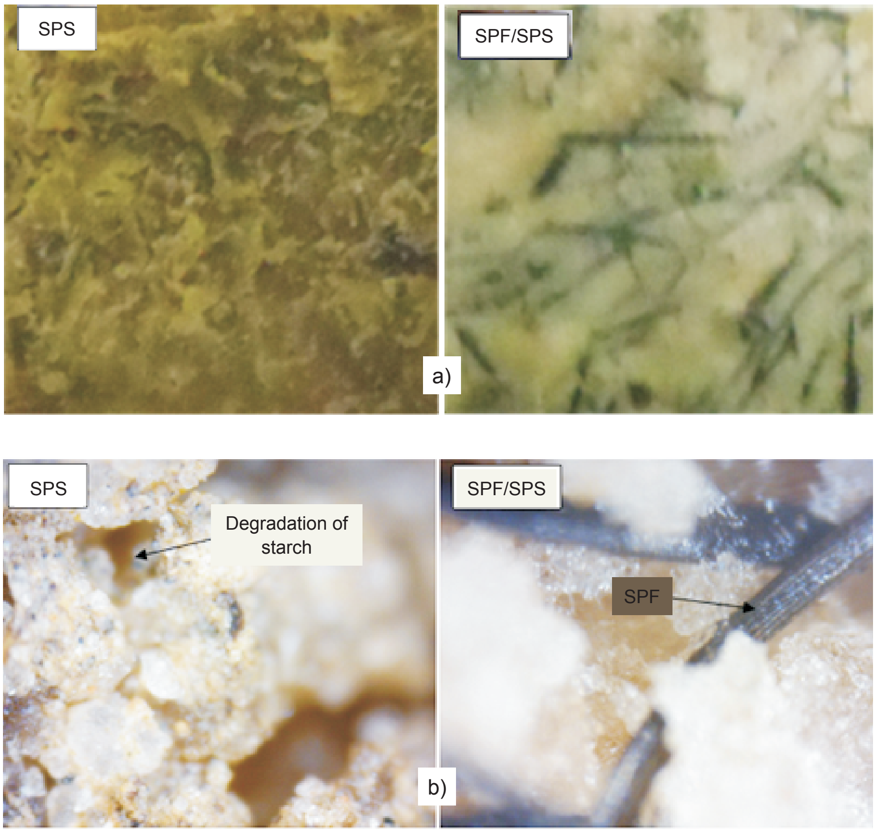

***Figure 3.** Surface morphology of SPS and SPF/SPS biocomposites; a) before and b) after being buried.*

composites after 72 h of being buried in compost soil. It can be seen that most of the starch had degraded in both the SPS and SPF/SPS biocomposites which was observed by the naked eye and a microscope, whereas the SPF had degraded less in the biocomposite. However, this degradation effect can be seen on the weight loss of the biocomposites, as explained earlier and observed in ***Figure 2***. Therefore it can be concluded that the addition of SPF delays the degradation of the biocomposite.

Conclusion

A novel biocomposite where both natural fibre and matrix are derived from underutilised parts of the sugar palm tree was successfully developed. From the investigation, it was found that the environmental effect on SPS and SPF/SPS biocomposite had brought about a loss of 78.09% and 53.67% in the tensile strength, respectively, at the end of 72 hrs of the weathering testing period. The biodegradation test showed that the SPS degraded faster with a weight loss of 63.58% at the end of 72 h as compared to SPF/SPS biocomposites where the loss was 56.7%. Thus this biocomposite shows good mechanical and biodegradable properties for applying it as packaging materials.

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