E-ISSN: 2829-7687
Journal of Fibers and Polymer Composites
Vol. 5 No. 2 (2026): 135-143

# Soil Burial Degradation and Morphology of PLA/Sugarcane Bagasse Biocomposites

Ahmad Hibatullah [a*], Salahuddin Junus [a], Mochamad Asrofi [a], R. A. Ilyas [b]

[a] Department of Mechanical Engineering, University of Jember, Jember, Indonesia
[b] Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, Skudai, 8, Johor, Malaysia

***Abstract.*** *This study aimed to investigate the degradation behavior and surface morphology of polylactic acid (PLA) biocomposites reinforced with sugarcane bagasse fibers (SCBF). The biocomposites were fabricated using the vacuum bagging technique with fiber loadings of 0, 22, 24, and 26 wt%. Their performance was evaluated through a 21-day soil burial test, water solubility test, and surface morphology analysis using a digital optical microscope. The results revealed that the incorporation of sugarcane bagasse fibers enhanced the biodegradation rate of the PLA biocomposites under soil burial conditions. The highest weight loss (17.02%) was obtained for the biocomposite containing 26 wt% SCBF after 21 days of burial, which was attributed to microbial activity and the hygroscopic nature of the natural fibers. In contrast, the addition of SCBF reduced the water solubility of the biocomposites due to the formation of a denser fiber network within the PLA matrix, which restricted water penetration and improved structural integrity. Morphological observations confirmed surface degradation after soil burial, as evidenced by the formation of cracks, fissures, and voids on the biocomposite surface. Overall, the incorporation of sugarcane bagasse fibers effectively improved the biodegradability of PLA biocomposites while maintaining lower water solubility, highlighting their potential for environmentally friendly packaging applications.*
***Keywords:*** *PLA biodegradation; sugarcane bagasse; vacuum bagging method; biocomposite morphology.*

**Type of the Paper:** Regular Article.

## 1. Introduction

The increasing demand for environmental protection has accelerated the development of environmentally friendly and biodegradable polymers. Biopolymers play a crucial role in mitigating the environmental impacts associated with conventional petroleum-based polymers while contributing to ecological sustainability. However, many biopolymers still exhibit inherent limitations, including poor mechanical properties, limited processability, and low thermal stability. Therefore, reinforcing fillers are commonly incorporated to improve their overall performance and broaden their potential applications [1]. The resulting materials are generally referred to as biocomposites.

Biocomposites are multiphase materials consisting of a biopolymer matrix reinforced with one or more types of natural fibers or particles [2]. Among the various biopolymers available,



https://doi.org/10.55043/jfpc.v5i2.614
Received May 14, 2026; Received in revised form July 3, 2026; Accepted July 4, 2026; Published July 27, 2026
* Corresponding author
Email: ahmad.hibatullah1922@gmail.com

polylactic acid (PLA) has attracted considerable attention owing to its biodegradability, biocompatibility, and processing characteristics, which are comparable to those of conventional thermoplastics. Nevertheless, PLA suffers from several drawbacks, particularly its high brittleness and low flexibility. One of the most effective approaches to overcome these limitations is the incorporation of natural fibers, such as cellulose, as reinforcing agents to enhance the mechanical performance of PLA-based composites [3].

In this study, sugarcane bagasse was selected as the reinforcing material because it is one of the most abundant agricultural residues generated worldwide. The utilization of sugarcane bagasse offers several advantages, including renewability, environmental friendliness, and low cost, making it a promising reinforcement material for large-scale biocomposite production [4]. Furthermore, sugarcane bagasse contains a relatively high cellulose content of approximately 45.03%, which contributes to the improvement of the mechanical properties of biocomposites [5].

Various fabrication techniques have been developed for producing biocomposites, including casting, hand lay-up, vacuum bagging, and three-dimensional (3D) printing. Among these methods, the vacuum bagging technique has attracted considerable interest because it is capable of producing composites with fewer defects, lower porosity, and improved structural quality [6]. Compared with the conventional hand lay-up technique, vacuum bagging has also been reported to produce composites with superior mechanical properties due to better fiber impregnation and more uniform resin distribution [7].

Previous studies have demonstrated that the incorporation of sugarcane bagasse as a reinforcing filler in PLA biocomposites can significantly improve their mechanical properties when used at an optimal filler loading [8,9]. However, to the best of the authors' knowledge, the biodegradation behavior of vacuum bagging-fabricated PLA/sugarcane bagasse biocomposites has not yet been reported. Therefore, this study investigates PLA biocomposites reinforced with sugarcane bagasse fibers at different filler loadings, fabricated using the vacuum bagging technique. The effects of sugarcane bagasse content (0, 22, 24, and 26 wt%) on soil burial degradation and water solubility were systematically evaluated.

## 2. Materials and methods

### *2.1. Materials*

The Sugarcane bagasse waste was obtained from street vendors in Jember, Indonesia. PLA (brand ESUN Eresin - PLA) was obtained from Zaiku 3D Shop in Surabaya, Indonesia. Various chemicals were used for fiber extraction, such as sodium hydroxide (NaOH) and distilled water to clean the fibers.

*2.2. Fiber processing*

The collected sugarcane bagasse was initially sun-dried until a constant weight was achieved. The dried bagasse was then cleaned to obtain high-quality fibers. The cleaned fibers were subjected to an alkaline treatment using a 4 wt% sodium hydroxide (NaOH) solution. Specifically, the fibers were immersed in a mixture of 4 wt% NaOH solution and 500 mL of distilled water for 4 h. After the alkali treatment, the fibers were thoroughly rinsed with distilled water until a neutral pH was reached and subsequently dried again until a constant weight was obtained.

*2.3. Biocomposite Fabrication*

The biocomposites were fabricated using the vacuum bagging technique by mixing PLA with sugarcane bagasse fibers (SBF) at different fiber loadings of 0, 22, 24, and 26 wt%. The prepared mixtures were placed into a mold according to the designated composition and subsequently sealed in a vacuum bag. Vacuum consolidation was then performed using a vacuum machine at a pressure of 0.5 bar. The molded biocomposites were cured under ultraviolet (UV) irradiation at a distance of 10 cm from the upper surface for 10 min to facilitate the solidification of the PLA matrix. After curing, the biocomposites were removed from the mold, stored under ambient conditions, and prepared for subsequent characterization and testing.

*2.4. Biodegradation Test*

The biodegradation test was evaluated based on the weight loss of the biocomposite samples. Specimens with dimensions of 10 mm × 20 mm were buried in soil at a depth of approximately 100 mm. The soil moisture was maintained through regular watering throughout the burial period. Prior to burial, each specimen was weighed to obtain its initial weight ($W_0$). The samples were then retrieved after 7, 14, and 21 days, cleaned, dried, and reweighed to determine the final weight ($W_t$). Each testing condition was performed in triplicate. The percentage of weight loss was calculated using the following equation, where $W_0$ represents the initial weight before soil burial and $W_t$ represents the final weight after soil burial.

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

*2.5. Water Solubility*

The water solubility test was conducted by immersing biocomposite specimens measuring 30 mm × 10 mm in distilled water for 21 days. The specimens were removed at predetermined immersion intervals of 7, 14, and 21 days. Each experimental condition was performed in triplicate. Before retrieval, the water was gently stirred to ensure uniform conditions. The specimens were then dried to a constant weight and weighed to determine the mass change at each immersion interval.

### *2.6. Optical Microscope*

The surface morphology of the biocomposites was analyzed using a digital optical microscope to examine the surface characteristics of the specimens after the biodegradation test. Morphological observations were conducted to evaluate the surface changes induced by the biodegradation process.

## 3. Results and Discussion

### *3.1 Soil Burial Testing*

The biodegradation behavior of biocomposite films is an important property to investigate because it is closely related to their potential application as environmentally friendly food packaging materials. Biodegradable films offer significant environmental advantages, as they can be converted into naturally occurring compounds through biological degradation processes [10]. During biodegradation, microorganisms degrade the polymer matrix through metabolic and enzymatic activities, breaking down high-molecular-weight biopolymers into lower-molecular-weight compounds that can be more readily assimilated by microorganisms [11]. When the polymer is completely decomposed into inorganic end products, such as carbon dioxide, water, and biomass, the process is referred to as mineralization [12]. In the present study, PLA biocomposites reinforced with 22, 24, and 26 wt% sugarcane bagasse fibers (SCBF), together with neat PLA as the control, were subjected to a soil burial biodegradation test under controlled soil moisture conditions.

Fig 1. Illustrates the weight loss of the biocomposites during the soil burial test. All specimens exhibited a gradual increase in weight loss with increasing burial time, indicating the progressive degradation of the biocomposites throughout the testing period. The neat PLA exhibited the lowest weight loss, with values of 6.96%, 12.66%, and 13.55% after 7, 14, and 21 days of burial, respectively. In contrast, all PLA/SCBF biocomposites showed greater weight loss than the neat PLA at each observation interval. This behavior can be attributed to the presence of lignocellulosic fibers, which are more susceptible to microbial attack than the PLA matrix [13]. Furthermore, increasing the fiber content enhances the accessibility of microorganisms and bacteria to the composite structure, thereby accelerating the biodegradation process [14]. The incorporation of natural fibers may also promote degradation by increasing moisture absorption, which facilitates water penetration into the composite and accelerates hydrolytic degradation of the PLA matrix [15]. These findings demonstrate that the incorporation of sugarcane bagasse fibers effectively enhances the biodegradation rate of PLA biocomposites, highlighting their potential for sustainable and environmentally friendly food packaging applications.

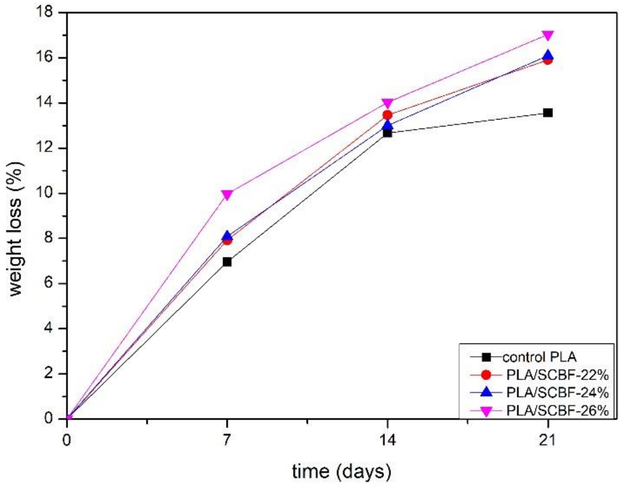


**Fig 1.** Weight Loss of PLA/SCBF Biocomposites and Pure PLA as a Function of Burial Soil Time

### *3.2 Water Solubility*

The water solubility test was conducted to evaluate the ability of bioplastic materials to dissolve when exposed to an aqueous environment [16]. Water solubility is an important characteristic of biodegradable films, particularly for food packaging applications, where an appropriate balance between water resistance and controlled solubility is required to maintain product integrity during use while ensuring environmental degradability after disposal [17]. Fig. 2 presents the water solubility of PLA/SCBF biocomposites containing different sugarcane bagasse fiber contents. The results indicate that the incorporation of sugarcane bagasse fibers into the PLA matrix reduced the water solubility of the biocomposites compared with neat PLA. This reduction is likely attributed to the formation of a denser and more compact composite structure, which restricts water diffusion and limits water penetration into the PLA matrix [18].

The lower water solubility of the PLA/SCBF biocomposites compared with neat PLA may also be associated with the reduced hydrophilic behavior of the reinforced composites, resulting in lower water uptake than the PLA matrix alone [19]. In addition, the presence of natural fibers contributes to maintaining the structural integrity of the composite by forming a reinforcing fiber network that suppresses material disintegration during water immersion [20]. Similar findings were reported by Jumaidin et al., who observed that the incorporation of sugarcane bagasse fibers significantly reduced the water solubility of biocomposites. Specifically, the addition of 15 wt% sugarcane bagasse fibers resulted in a water solubility of 24.41%, whereas neat PLA exhibited a substantially higher solubility of 62.12% [21]. These results suggest that the incorporation of natural fibers can effectively reduce the hygroscopic behavior of thermoplastic matrices, thereby improving their water resistance while maintaining their potential as biodegradable materials [22].

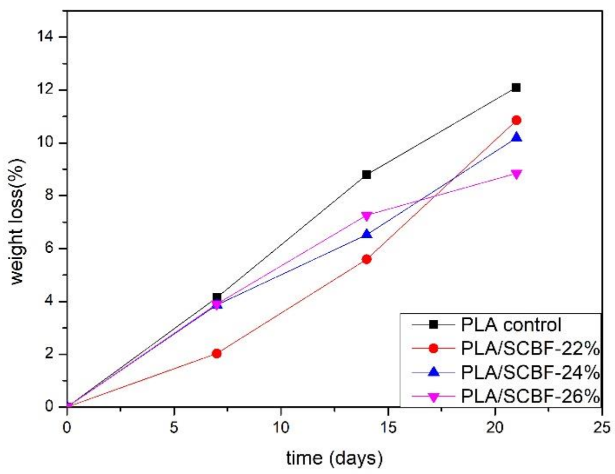


**Fig 2.** Water Solubility of PLA/SCBF Biocomposite

*3.3 Biocomposite Morphology*

Fig. 3 presents the surface morphology of the biocomposites observed using a digital optical microscope before and after the soil burial biodegradation test. Prior to soil burial (Fig. 3a), the biocomposite surface appeared relatively smooth and homogeneous, with no visible signs of surface damage. In contrast, after soil burial (Fig. 3b–d), noticeable morphological changes were observed, including the formation of elongated cracks, surface fissures, and small voids. The appearance of these cracks indicates the onset of surface degradation caused by the progressive deterioration of the PLA matrix during the biodegradation process [23]. As biodegradation progressed, the cracks propagated into larger fissures and were accompanied by the formation of surface voids, resulting in a rougher surface morphology compared with that of the untreated biocomposites [24].

The biodegradation of PLA-based biocomposites in a soil environment is a complex process influenced by various biotic and abiotic factors, including soil moisture, temperature, and microbial activity [24]. During soil burial, water initially diffuses into the PLA matrix, triggering hydrolytic degradation that reduces the molecular weight of the polymer. This process is subsequently followed by microbial activity, which further accelerates material degradation [25]. These combined degradation mechanisms promote the progressive development of cracks, fissures, and voids, leading to a rougher biocomposite surface as the burial period increases [23,24,26]. Furthermore, the biocomposites reinforced with modified cellulose fibers exhibited greater hydrophobicity, as evidenced by their higher water contact angle values [26]. This enhanced hydrophobicity is expected to reduce water diffusion into the PLA matrix, thereby slowing the hydrolytic degradation process and limiting the extent of surface deterioration during soil burial [25].

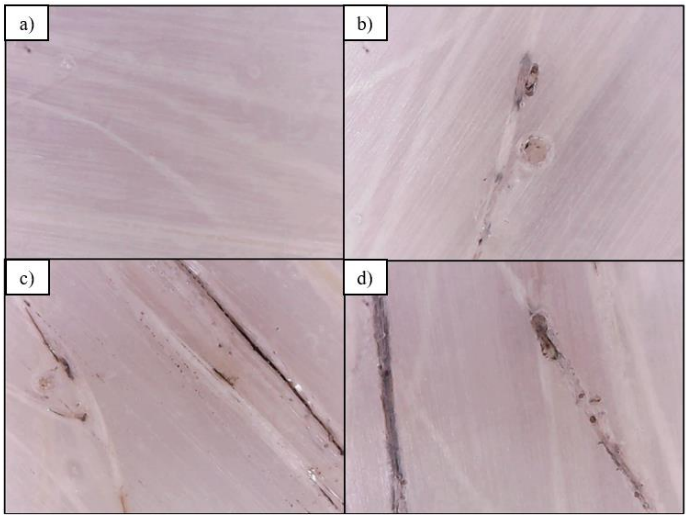


**Fig 3.** Morphologies of Biocomposite PLA/SCBF a) Before Soil Burial, (b-d) After Soil Burial

## 4. Conclusions

PLA biocomposites reinforced with sugarcane bagasse fibers (SCBF) were successfully fabricated using the vacuum bagging technique. The results demonstrated that the incorporation of SCBF enhanced the biodegradation rate of the biocomposites during the soil burial test. The biocomposite containing 26 wt% SCBF exhibited the highest biodegradation rate, with a weight loss of 17.02%, indicating that the presence of sugarcane bagasse fibers promoted degradation through the combined action of microorganisms and bacteria. In contrast, the PLA/SCBF biocomposites exhibited lower water solubility than neat PLA, suggesting that the incorporation of natural fibers improved the structural stability of the biocomposites by forming a reinforcing fiber network within the PLA matrix, thereby reducing material disintegration during water immersion. Morphological observations further confirmed the occurrence of surface degradation after soil burial, as evidenced by the formation of cracks, fissures, and voids on the biocomposite surface. These morphological changes are attributed to hydrolytic degradation of the PLA matrix, followed by microbial activity, which progressively deteriorated the surface structure of the biocomposites.

## References

[1] Sun J, Shen J, Chen S, Cooper MA, Fu H, Wu D, et al. Nanofiller Reinforced Biodegradable PLA/PHA Composites: Current Status and Future Trends. Polymers (Basel) 2018;10:505. https://doi.org/10.3390/polym10050505.

[2] Asrofi M, Arisandi HD, Pradiza RR, Junus S, Mahardika M, Amanda P, et al. Mechanical Properties of Biocomposite Films Based Polyvinyl Alcohol/Potato Starch Filled by Coffee Ground Waste. International Journal of Agriculture and Biosciences 2024:525–30. https://doi.org/10.47278/journal.ijab/2024.156.

[3] Ruz-Cruz MA, Herrera-Franco PJ, Flores-Johnson EA, Moreno-Chulim MV, Galera-Manzano LM, Valadez-González A. Thermal and mechanical properties of PLA-based multiscale cellulosic biocomposites. Journal of Materials Research and Technology 2022;18:485–95. https://doi.org/10.1016/j.jmrt.2022.02.072.

[4] Andrianto SNK, Gapsari F, Wijayanti W. Karakterisasi serat ampas tebu sebagai penguat komposit bioplastik. N: Seminar Nasional LPPM UMMAT 2023;2. Available from: https://journal.ummat.ac.id/index.php/semnaslppm/article/view/14702.

[5] Yao S, Nie S, Zhu H, Wang S, Song X, Qin C. Extraction of hemicellulose by hot water to reduce adsorbable organic halogen formation in chlorine dioxide bleaching of bagasse pulp. Ind Crops Prod 2017;96:178–85. https://doi.org/10.1016/j.indcrop.2016.11.046.

[6] Muralidhara B, Kumaresh Babu SP, Suresha B. Utilizing vacuum bagging process to prepare carbon fiber/epoxy composites with improved mechanical properties. Mater Today Proc 2020;27:2022–8. https://doi.org/10.1016/j.matpr.2019.09.051.

[7] Abdurohman K, Satrio T, Muzayadah NL, Teten. A comparison process between hand lay-up, vacuum infusion and vacuum bagging method toward e-glass EW 185/lycal composites. J Phys Conf Ser 2018;1130:012018. https://doi.org/10.1088/1742-6596/1130/1/012018.

[8] Bartos A, Nagy K, Anggono J, Antoni, Purwaningsih H, Móczó J, et al. Biobased PLA/sugarcane bagasse fiber composites: Effect of fiber characteristics and interfacial adhesion on properties. Compos Part A Appl Sci Manuf 2021;143:106273. https://doi.org/10.1016/j.compositesa.2021.106273.

[9] Wang L, Tong Z, Ingram LO, Cheng Q, Matthews S. Green Composites of Poly (Lactic Acid) and Sugarcane Bagasse Residues from Bio-refinery Processes. J Polym Environ 2013;21:780–8. https://doi.org/10.1007/s10924-013-0601-3.

[10] Dirpan A, Ainani AF, Djalal M. A Review on Biopolymer-Based Biodegradable Film for Food Packaging: Trends over the Last Decade and Future Research. Polymers (Basel) 2023;15:2781. https://doi.org/10.3390/polym15132781.

[11] Ilyas RA, Sapuan SM, Ibrahim R, Abral H, Ishak MR, Zainudin ES, et al. Thermal, Biodegradability and Water Barrier Properties of Bio-Nanocomposites Based on Plasticised Sugar Palm Starch and Nanofibrillated Celluloses from Sugar Palm Fibres. J Biobased Mater Bioenergy 2020;14:234–48. https://doi.org/10.1166/jbmb.2020.1951.

[12] Tahri N, Bahafid W, Sayel H, El Ghachtouli N. Biodegradation: Involved Microorganisms and Genetically Engineered Microorganisms. Biodegradation - Life of Science, InTech; 2013. https://doi.org/10.5772/56194.

[13] Yaacob ND, Ismail H, Sung Ting S. Soil Burial of Polylactic Acid/Paddy Straw Powder Biocomposite. Bioresources 2015;11. https://doi.org/10.15376/biores.11.1.1255-1269.

[14] Pandit A, Kumar R. A Review on Production, Characterization and Application of Bacterial Cellulose and Its Biocomposites. J Polym Environ 2021;29:2738–55. https://doi.org/10.1007/s10924-021-02079-5.

[15] Rajesh G, Ratna Prasad AV, Gupta AVSSKS. Soil Degradation Characteristics of Short Sisal/PLA Composites. Mater Today Proc 2019;18:1–7. https://doi.org/10.1016/j.matpr.2019.06.270.

[16] Nurhabibah SA, Kusumaningrum WB. Karakterisasi Bioplastik Dari K-Karagenan Eucheuma Cottonii Terplastisasi Berpenguat Monoselulosa. Jurnal Kimia Dan Kemasan 2021;43:82. https://doi.org/10.24817/jkk.v43i2.6808.

[17] DOGAN HY, TERZİOĞLU P, DUMAN Ş. Polylactic acid/akermanite biocomposite films for food packaging applications. Journal of Polymer Research 2024;31:195. https://doi.org/10.1007/s10965-024-04033-0.

[18] Ren H, Li S, Gao M, Xing X, Tian Y, Ling Z, et al. Preparation and Characterization of Microcrystalline Cellulose/Polylactic Acid Biocomposite Films and Its Application in Lanzhou Lily (Lilium davidii var. unicolor) Bulbs Preservation. Sustainability 2023;15:13770. https://doi.org/10.3390/su151813770.

[19] Maran JP, Sivakumar V, Thirugnanasambandham K, Sridhar R. Degradation behavior of biocomposites based on cassava starch buried under indoor soil conditions. Carbohydr Polym 2014;101:20–8. https://doi.org/10.1016/j.carbpol.2013.08.080.

[20] Jumaidin R, Ab Rahman, Mohd Hidayat, Ahmad MN, Wahi MK, Yaakob MY, et al. Characteristics of cogon grass fibre reinforced thermoplastic cassava starch biocomposite:

Water absorption and physical properties. Jurnal of Advanced Research in Fluid Mechanics and Thermal Sciences 2019;1:43–52. Available from: https://eprints.utem.edu.my/id/eprint/24531/.
[21] Jumaidin R, Ilyas RA, Saiful MS, Hussin F, Mastura MT. Water transport and physical properties of sugarcane bagasse fibre reinforced thermoplastic potato starch biocomposite. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences 2019;61:273–81. Available from: https://www.researchgate.net/publication/336253345.
[22] Gáspár M, Benkő Zs, Dogossy G, Réczey K, Czigány T. Reducing water absorption in compostable starch-based plastics. Polym Degrad Stab 2005;90:563–9. https://doi.org/10.1016/j.polymdegradstab.2005.03.012.
[23] Gunti R, Ratna Prasad AV, Gupta AVSSKS. Mechanical and degradation properties of natural fiber-reinforced PLA composites: Jute, sisal, and elephant grass. Polym Compos 2018;39:1125–36. https://doi.org/10.1002/pc.24041.
[24] Siakeng R, Jawaid M, Asim M, Siengchin S. Accelerated Weathering and Soil Burial Effect on Biodegradability, Colour and Textureof Coir/Pineapple Leaf Fibres/PLA Biocomposites. Polymers (Basel) 2020;12:458. https://doi.org/10.3390/polym12020458.
[25] Budin S, Che Maideen N, Koay MH, Yusoff H, Ghafar H. Comparative study on Degradation of Polylactic Acid/ Syzygium Aromaticum Composites Ageing in Outdoor Environment and Soil Burial. IIUM Engineering Journal 2022;23:396–411. https://doi.org/10.31436/iiumej.v23i1.2138.
[26] Spiridon I, Darie RN, Kangas H. Influence of fiber modifications on PLA/fiber composites. Behavior to accelerated weathering. Compos B Eng 2016;92:19–27. https://doi.org/10.1016/j.compositesb.2016.02.032.