

Preparation and Properties of Biocomposite Based on Natural Rubber and Bagasse Nanocellulose

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Abstract. Biocomposite based on natural rubber (NR) and bagasse nanocellulose (BNC) was prepared in latex state. The mechanical, morphological and thermal properties of NR/BNC biocomposite were investigated. It was found that the addition of 3 wt% of BNC in NR film caused significant increase in modulus at 100% and 300% elongations and improved thermal stability of NR/BNC biocomposite. However, the strength at break and elongation at break of the biocomposite were not enhanced correlating to the morphological result obtained from scanning electron microscope (SEM).

1 Introduction

In recent years, biocomposites have received much attention to replace petrochemical based materials because the environmental awareness and the international demand for green technology. Extensive work has been done to incorporate natural fiber into polymer matrix to develop sustainable materials which meet up the recent demand of lightweight composites with high specific strength and modulus. Bagasse fiber is one of natural fibers made from by-product of sugar cane industry. There have been a number of researches exploring the use of bagasse fiber to reinforce natural rubber [1-3]. They found that the addition of bagasse fiber in natural rubber matrix improved tensile strength and barrier properties and increased rate of degradation of the rubber in soil. In this work, another form of bagasse fiber, the bagasse nanocellulose (BNC) powder, was used to reinforce natural rubber film. The properties of NR/BNC biocomposite including mechanical, morphological and thermal properties were investigated.

2 Experimental

2.1 Materials

High ammonia (HA) natural rubber concentrated latex with 60% of dry rubber content was supplied by the Key Laboratory of Ministry of Agriculture for Natural Rubber Processing Zhanjiang, China. The bagasse nanocellulose (BNC) powder with particle size range of 5-12 nm was extracted from bagasse cellulose by high pressure homogenization (HPH) according to the method described elsewhere [4]. The BNC powder was dried at 50°C for 24 h in hot air oven before used to remove moisture. Characterization of unmodified bagasse nanocellulose was accomplished by FTIR spectroscopy as shown in Fig. 1.

2.2 Preparation of NR/BNC biocomposite

Natural rubber biocomposite reinforced with 3 wt% of bagasse nanocellulose was prepared in latex stage. The BNC powder was first dispersed in DI water and sonicated for 30 min. NR latex and the suspension of BNC were mixed by using magnetic stirrer for 2 h at room temperature. The mixture was cast in Teflon mold and then left at room temperature for 48 h. After that, the NR/BNC film was dried in vacuum oven at 50°C for another 48 h to obtain final dry film around 1 mm thick.

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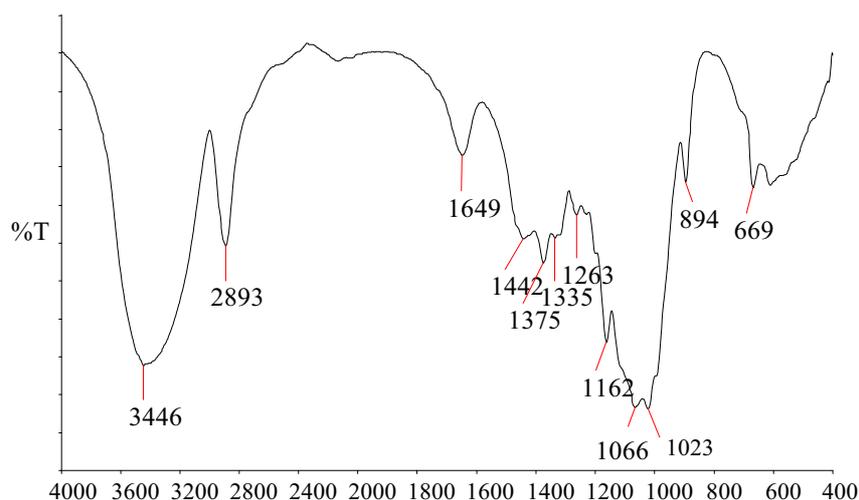


Figure. 1. FTIR spectrum of bagasse nanocellulose

2.3 Measurement

The mechanical properties of dried film were analyzed by Hounsfield H10KS universal testing machine based on ASTM D412 at a crosshead speed of 500 mm/min using five samples. Scanning electron microscope (SEM) (Philips XL 30-EDAX microscope) was used to study the morphology of cross-sectional sample. The sample was frozen under liquid nitrogen, fractured, coated with gold/palladium and observed using an accelerating voltage of 1.0 kV. Thermogravimetric analysis (TGA) was carried out using a Perkin Elmer (TGA7) instrument, in N₂ atmosphere at 10°C/min heating rate, from 30 to 650°C.

3 Results and discussion

3.1 Mechanical properties of NR/BNC

Mechanical properties of unvulcanized NR films with and without 3 wt% BNC were investigated by tensile test at room temperature. The stress-strain curves of NR and NR/BNC films are shown in Fig. 2. The median values of moduli at 100% and 300% elongations, tensile strength and elongation at break are reported in Table 1.

Fig. 2 shows stress-strain curves of natural rubber and bagasse nanocellulose filled natural rubber films without vulcanization. It can be seen that the incorporation of unmodified bagasse nanocellulose particles in the natural rubber increased the initial stress, which indicated increasing of stiffness.

Table 1. Mechanical properties of uncured NR and NR/BNC biocomposite.

Samples	M100 (MPa)	M300 (MPa)	Tensile strength (MPa)	Elongation at break (%)
NR	0.33	0.36	1.16	915
NR/BNC	0.47	0.53	1.11	793

Table 1 shows the tensile moduli at 100% and 300% elongations, tensile strength and elongation at break of NR and NR/BNC biocomposite. It can be clearly seen that the incorporation of BNC particles increased tensile modulus of natural rubber. It is noted that tensile modulus refers to the stiffness or ability of materials to resist the deformation. Therefore, addition of stiff particles into the soft polymer matrix markedly improves in stiffness of the filled system [5]. However, tensile strength of the composite slightly decreased with the presence of BNC

particles. This can be explained due to poor dispersion of the BNC particles in the NR matrix. Hydroxyl groups on surface of unmodified BNC particles (appearing at wavenumbers of 3446 and 669 cm⁻¹ as shown in Fig. 1) exhibited strong hydrophilic nature. Therefore, the hydrophilic BNC particles could not disperse well in hydrophobic natural rubber matrix as proven by SEM result shown in Fig. 3.

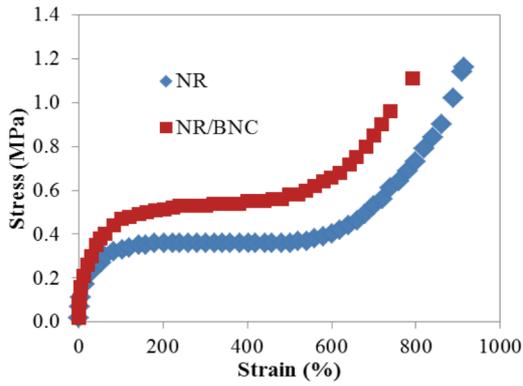


Figure. 2. Typical stress-strain curves of uncured NR and NR/BNC composite

3.2 Morphological property

As seen in Fig. 3(A) and (B), the SEM micrographs of BNC powder show spherical shape with diameters 100-200 nm. However, the nanoparticles are gathered together to form large agglomerated particles. This is due to the functional groups on surface of unmodified BNC tended to agglomerate through hydrogen bonding. The formation of agglomerates in NR matrix (Fig. 3(C)) caused additional stress concentrators leading to increased chances of failure, which finally reduced tensile strength and elongation at break of the biocomposite.

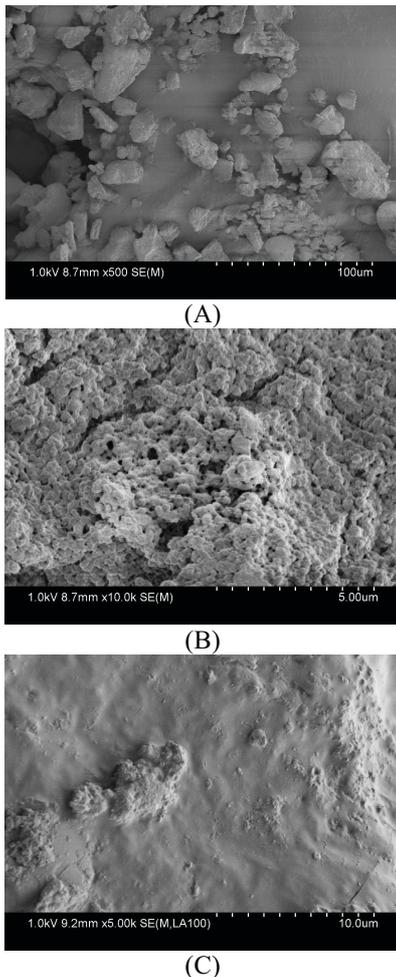


Figure. 3. Morphology of bagasse nanocellulose (A: 500x and B: 10000x) and fractured surface of NR/BNC biocomposite.

3.3 Thermal properties

Fig. 4 shows the TGA and DTG curves, respectively, of NR, BNC and NR/BNC biocomposites. The thermal decomposition of BNC consisted of two decomposition steps. The first stage of decomposition was the evaporation of absorbed moisture in the cellulose. The second stage of decomposition corresponded to the main decomposition of the nanocellulose [4]. The DTG curves showed that BNC was maximum degraded at the temperatures of 337.6°C. NR and NR/BNC show one-step decomposition process and the maximum decomposition was given at 374.5 and 376.6°C, respectively. From DTG curve, the decomposition rate of NR/BNC reduced comparing with NR. This can be attributed that the incorporation of 3 wt% of BNC in NR increased thermal stability of NR matrix.

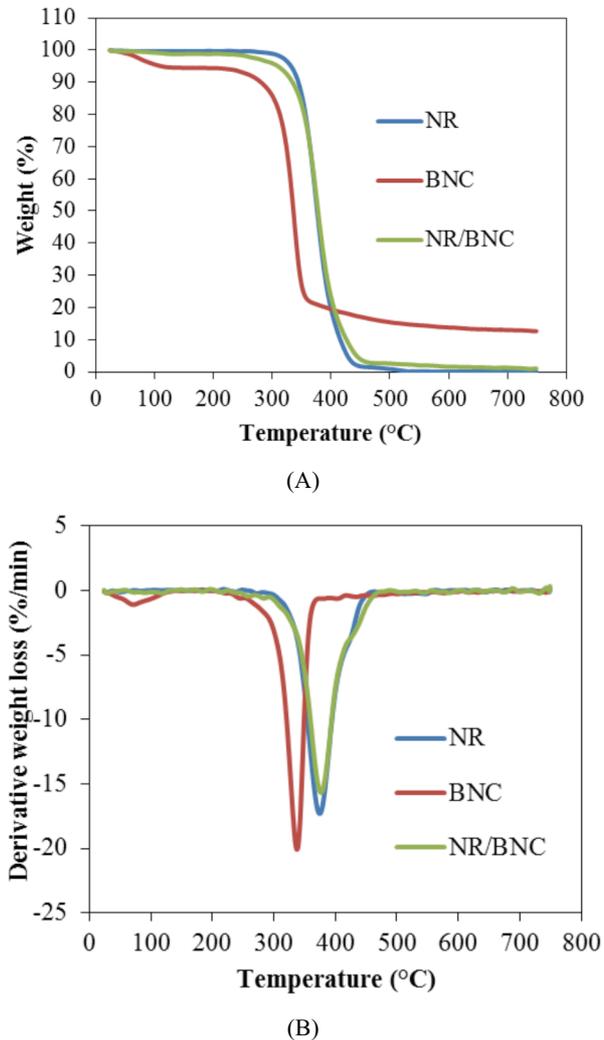


Figure. 4. Thermogravimetric analysis (TGA) (A) and derivative thermogravimetric (DTG) (B) curves for NR, BNC and NR/BNC.

4 Summary

Biocomposite of natural rubber and bagasse nanocellulose was successfully prepared in latex stage. The addition of 3 wt% of nanocellulose in natural rubber enhanced modulus and thermal stability of the rubber matrix. However, the agglomeration of bagasse

nanocellulose caused the reduction of tensile strength and elongation at break of natural rubber. This is due to the incompatibility between hydrophilic surface of bagasse nanocellulose and hydrophobic natural rubber. To solve this problem, our further work will focus on surface modification of bagasse nanocellulose.

Acknowledgments

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