



Exploring the effect of cellulose nanowhiskers isolated from oil palm biomass on polylactic acid properties



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ABSTRACT

In this work, polylactic acid (PLA) reinforced cellulose nanowhiskers (CNW) were prepared through solution casting technique. The CNW was first isolated from oil palm empty fruit bunch microcrystalline cellulose (OPEFB-MCC) by using 64% H₂SO₄ and was designated as CNW-S. The optical microscopy revealed that the large particle of OPEFB-MCC has been broken down by the hydrolysis treatment. The atomic force microscopy confirmed that the CNW-S obtained is in nanoscale dimension and appeared in individual rod-like character. The produced CNW-S was then incorporated with PLA at 1, 3, and 5 parts per hundred (phr) resins for the PLA-CNW-S nanocomposite production. The synthesized nanocomposites were then characterized by a mean of tensile properties and thermal stability. Interestingly to note that incorporating of 3 phr/CNW-S in PLA improved the tensile strength by 61%. Also, CNW-S loading showed a positive impact on the Young's modulus of PLA. The elongation at break (E_b) of nanocomposites, however, decreased with the addition of CNW-S. Field emission scanning electron microscopy and transmission electron microscopy revealed that the CNW-S dispersed well in PLA at lower filler loading before it started to agglomerate at higher CNW-S loading (5 phr). The DSC analysis of the nanocomposites obtained showed that T_g , T_{cc} and T_m values of PLA were improved with CNW-S loading. The TGA analysis however, revealed that incorporated CNW-S in PLA effect the thermal stability (T_{10} , T_{50} and T_{max}) of nanocomposite, where it decrease linearly with CNW-S loading.

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1. Introduction

Recently, plethora studies have been done on the different approach in production and isolation of cellulose nanoparticle [1–5]. The use of this nanoparticles as a reinforcement phase in the composite production has attracted huge interest among researchers [1–7]. The principal reasons for the utilization of cellulosic materials are its high specific strength and modulus compared to other engineering materials, and its reinforcing potential [8]. Due to their availability, ease of chemical and mechanical modification as well as their biocompatibility, renewability and a high axis ratio (L/d), cellulose nanoparticles have attracted enormous attention as

an alternative to micro-sized reinforcements in composite materials [1,9]. It is well known that native cellulose can be readily hydrolyzed to micro or nanocrystalline. Hydrolysis of lignocelluloses has been reported to result in micro or nanocrystalline cellulose [1]. It was reported that these nanocrystalline cellulose or cellulose nanowhisker (CNW) are usually ~100–300 nm in length and ~3–10 nm in width [10,11]. The term whiskers are used to designate elongated crystalline rod-like nanoparticles, whereas the designation nanofibrils should be used to designate long flexible nanoparticles consisting of alternating crystalline and amorphous strings [3].

The use of CNW as reinforcement material will lead to a fully degradable and renewable biodegradable nanocomposite [12]. CNW have been obtained after the removal of the amorphous region that result in the formation of high-purity single crystals. This material has a mechanical strength equivalent to the binding forces of adjacent atoms [3]. The resultant highly ordered structure produces not only unusually high strength but also significant changes in electrical, optical, magnetic, dielectric,

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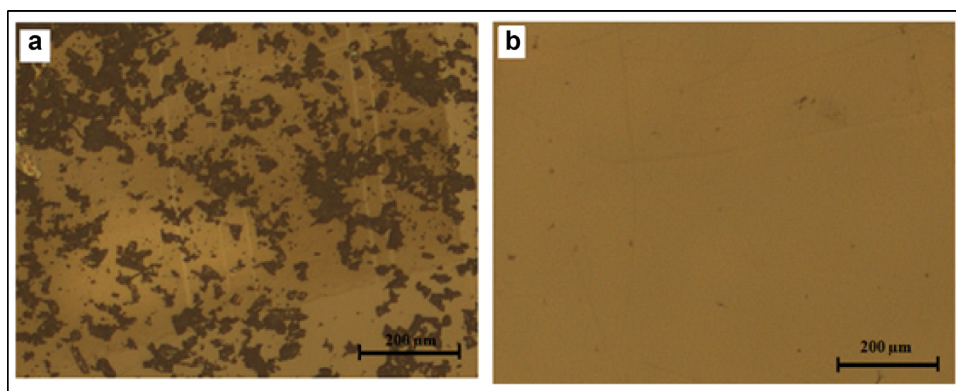


Fig. 1. Optical micrograph images for (a) before hydrolysis (b) after hydrolysis.

conductive, and even superconductive properties. The tensile strength properties of whiskers allow the processing of the highest attainable composite strengths and high-volume content reinforcements [13,14].

A disadvantage of CNW is that the crystallites have to be isolated, and incorporation of the crystallites in a matrix usually involves problems in controlling the dispersion level [13,14]. However, according to Pandey et al. exposure to mechanical dispersion or ultrasonication would permit the dispersion of CNW aggregates and finally produce stable colloidal suspensions [15]. In addition proper treatment of MCC with sulfuric acid (H_2SO_4) will not only generate isolated cellulose whiskers but also a negatively charged surface resulting from the esterification of hydroxyl groups by sulphate ions formed a stable colloid system [16]. These nanomaterials which show unique properties when incorporated in different polymers have been sourced from kraft pulp, sugar beet pulp, wheat straw, bacterial cellulose, and hemp fiber [17].

Malaysia is currently acclaimed as the largest producer and exporter of palm oil in the world. Earlier studies by Basiron [18], showed that the Palm Oil industry in Malaysia generates more than 18 million tonnes of palm oil annually, thus becoming a major economic pillar for the country. Consequently, enormous amounts of lignocelluloses residues from oil palm industry such as oil palm empty fruit bunches (OPEFB) were generated by the palm oil industry [19]. OPEFB, a non-woody fibrous residue, which remains after the liquid oil has been extracted, has not received much commercial utilization. This biomass is readily available at minimal cost. The development of a technique that can process these bio-residuals into high-value added product (i.e., CNW) is of

great interest. Therefore this study focused on the isolation of CNW from oil palm empty fruit bunches microcrystalline (OPEFB-MCC) by acid hydrolysis technique and designated as CNW-S. The nano-sized cellulose particle obtained was then used as reinforcement phase in the polylactid acid (PLA) matrices for the development of green nanocomposites (PLA-CNW-S). PLA is biopolymers which can be derive from the fermentation of corn. It has good mechanical and biodegradable properties. However, due to low thermal stability, slow degradation rate, and medium gas barrier properties limited the use of this biopolymer [16]. Therefore incorporating PLA with the renewable reinforcement filler like CNW-S could be of great interest in order to enhance some of PLA limitation while maintaining their transparency and biodegradability properties.

2. Materials and methods

2.1. Material

Polylactic acid (Nature WorkTM PLA 3001D) in pellet form was obtained from NatureWork[®] LLC, Minnetonka, MN USA. It has a specific gravity 1.24 g/cm^3 and melt flow index (MFI) around 15 g/10 min ($190^\circ\text{C}/2.16\text{ kg}$). All chemicals were used as received and were secured from Merck, Malaysia.

2.2. Preparation of PLA and PLA-CNW-S nanocomposites

A CNW-S was produced from OPEFB-MCC and used as reinforcement filler. The production of OPEFB-MCC and CNW-S were described in detail in author's early publication [6,20]. A 10 wt%

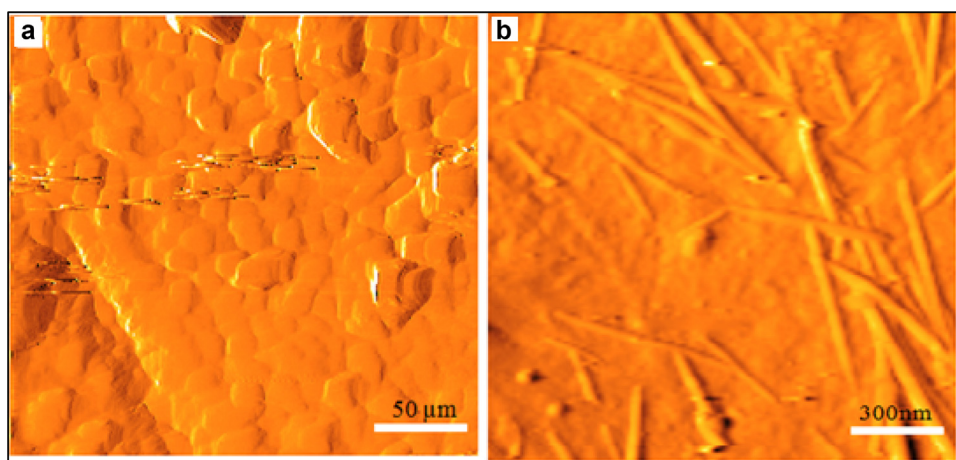


Fig. 2. The AFM images for (a) OPEFB-MCC and (b) CNW-S.

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