Oil Palm Biomass as a Resource for Sustainable Production of Cellulose Nanofiber

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Abstract: In this study, cellulose nanofiber (CNF) was produced from oil palm biomass (OPB) by using a wet disk mill (WDM). It was exhibited that the produced CNF had diameter in the range of 10-30 nm. When blended with low density polyethylene (LDPE) at 3 wt% CNF, the biocomposites resulted in an increment in tensile strength and flexural strength by 55% and 195% as compared to neat LDPE. Despite of the CNF ability to improve mechanical properties of the biocomposites, the CNF production suffers in term of high energy requirement due to the intense mechanical processing. Herewith, it is suggested that a sustainable production of CNF from OPB can be achieved by coupling the process with palm oil processing which is currently generating excess steam energy equivalent to 3.64 GW h/y, to create an overall palm oil mill biorefinery which includes material production.

Keywords: Cellulose nanofiber, oil palm biomass, biorefinery, biocomposites, palm oil mill

INTRODUCTION

Malaysia is the world's second largest producer and exporter of palm oil, and palm oil industry has been one of the biggest contributor to Malaysia gross national income. About 19 million tonnes of crude palm oil (CPO) is being produced per year. The amount of CPO extracted represents only 20% of the total weight of fresh fruit bunches (FFB) being processed during palm oil processing, hence abundance of residues are actually being generated during the process. In total, there is about 26 million tonnes of solid biomass being produced from the palm oil mill annually (AIM, 2013). There have been numerous research conducted in order to propose for the potential utilization of these biomass. Since the major component of oil palm biomass is cellulose, oil palm biomass is a good candidate for cellulose nanofiber (CNF) production. CNF is cellulosic material with one of its dimension in nanoscale, and has many potential applications, such as in composite products, paper, packaging material, food and biomedical devices. In this study, CNF is produced from oil palm biomass by using mechanical approach, *i.e.* by using a wet disk mill (WDM).

MATERIALS AND METHODS

Materials and Pretreatment

OPMF was collected from Seri Ulu Langat Palm Oil Mill, Selangor, Malaysia. The fiber was disintegrated, washed, and dried. OPMF was pretreated by totally chlorine free (TCF) solvent and 6 wt% potassium hydroxide (KOH) for cellulose isolation.

Preparation of cellulose nanofiber and biocomposites
CNF was produced by using a high shear ultrafine friction grinder known as a wet disk mill, WDM (Multi mill, Grow Engineering, Adachi-ku, Tokyo, Japan). 1 wt% fiber suspension in water was passed through the grinder for up to 20 cycles at 1,800 rpm.
Nanocomposites of PE/ PE*g*MA/CNF (97/0.5~5 wt/wt) were prepared using a Brabender Plastograph EC internal mixer (Brabender GmbH & Co. KG, Germany) with a mixing speed 50 rpm for 20 min at 160 °C. Resulted composites were characterized for mechanical properties.

RESULTS AND DISCUSSION

CNF was successfully produced from oil palm biomass by WDM, with average diameter of 10 - 30 nm. The CNF was incorporated in PE, and it was found that the best mechanical properties were obtained when 3 wt% of CNF was incorporated in the PE matrix, with the increment by almost 55 and 195 % in tensile strength and flexural strength, respectively, compared to PE.

Table. Mechanical properties of PE/CNF composites

Samples	Tensile strength (MPa)	Young's modulus (MPa)	Flexural strength (MPa)	Flexural modulus (MPa)
PE / MAgPE	7. 8 ± 0.3	110 ± 0.01	5.6 ± 0.5	219.2 ± 17.6
0.5% CNF / PE/ MAgPE	9.2 ± 0.7	141 ± 0.01	8.2 ± 0.3	222.7 ± 5.4
1% CNF / PE/ MAgPE	11 ± 0.3	150 ± 0.02	12.2 **±** 2.2	245.8 ± 8.6
3%CNF / PE/ MAgPE	12.1 ± 0.1	166 ± 0.01	16.5 ± 0.2	273 ± 2.2
5% CNF / PE/ MAgPE	9.3 ± 0.5	101 ± 0.01	10.5 ± 0.8	234.1 ± 3.3

This great effect of CNF exhibits the potential of CNF from oil palm biomass as additive in biocomposites to improve the mechanical properties of polymeric materials. Nevertheless, general issue with the utilization of CNF relates to its high cost, due to the processing method which requires high energy consumption. Palm oil industry has excess steam energy equivalent to 3.64 GW h/y which is currently being untapped (Abdullah et al., 2016). This available steam energy could be used as a source of power for generating CNF.

CONCLUSIONS
Oil palm biomass could be used as raw material for cellulose nanofiber production, with superior morphological property (diameter less than 30 nm). This contributes to the improved mechanical properties of the polymeric composites. For sustainable CNF production from OPB, the excess steam available from palm oil mill could be used as a source of energy.

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