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Development of value-added Biomaterials from Oil Palm Agro-wastes

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***Abstract*— There is a wide spread availability and massive generation of oil palm agro wastes in Malaysia. This calls for co-ordinated effort to manage the wastes and to develop value added products from them. Empty Fruit Bunch (EFB) can be treated by physical and chemical processes to extract oil and cellulose. Cellulose is composed of a set of parallel chains of glucose molecule with anhydroglucose unit that has three hydroxyl carbon available (C-2, C-3& C-6) for derivatization. Cellulose chains form a highly ordered structure known as microfibril. Highly crystalline forms of cellulose are difficult to work with and often unpredictable in behaviour. Non-crystalline form on the other hand could be produced that would open up new possibilities for cellulosic-based biopolymers. Mesophases of cellulose could determine the order of molecular orientation, anisotropy of fiber. High tensile strength fiber depends upon the molecular arrangement in the cellulose crystallites.**

Keywords-Oil Palm Empty fruit bunch, agro-wastes, lignocellulosic materials, liquid crystalline, nanofibers, biomaterials, molecular-preferred orientation.

I. INTRODUCTION

Oil Palm (*Elaeis guineensis*) is the most important species in *Elaeis* genus which belongs to the family Palamae [1]. It is cultivated in West Africa and in all tropical areas especially in Malaysia, Indonesia and Thailand. The oil palm fruit is reddish in colour and has a size of large plum, and grows in large bunches. A bunch usually has the weight of 10 to 40 kg. Each fruit consists of a single seed (the palm kernel) and surrounded by a soft oily pulp mesocarp. Oil is extracted from both the fruit pulp and the kernel. The oil extracted from fruit pulp is used for edible purposes, whilst the extracted oil from kernel is used for the manufacturing of soap [2]. Palm oil has now become world's largest source of edible oil with 38.5 million tones or 25% of the world's total oil and fat production [3]. In 2006, Indonesia was the world's largest producer of palm oil with 15.9 million tonnes of oil or 44% of the world's total export. Malaysia comes close second with 15.88 million tonnes or 43% of the world's total export [4]. In 2007, productive oil palm plantation in Malaysia was 4.3 million hectares, which was 3.4% increase from previous year [5]. One hectare of oil palm plantation could produce about 50-70 tonnes of biomass residues [6]. In 2005, about 55.73 million tonnes of oil palm biomass was recorded. Currently 85.5% out of more than 70 million tonnes of biomass is generated by Malaysian Oil Palm Industries [7,8]. The types of oil palm biomass include empty fruit bunch (EFBs), fiber, shell, wet shell, palm kernel, fronds and trunks [9].

In this study, the development of value-added biomaterials from oil palm agro waste is discussed. The review presented will be of great interest to the existing oil palm mill as a new economic model.

II. BACKGROUND

Empty fruit bunches (EFBs) can be a source of biopolymers such as polyhydroxyalkonates (PHAs) and polylactate (PLA) [10]. Bioplastics have similar characteristics as petroleum derivatives used for packaging material. In bioplasic production, sugar is obtained from the EFB which is used as a cheap carbon source in bacterial fermentation. Starch and Cellulose are first converted into organic acids like lactic acids which are then polymerized to form bioplastic. EFB has been used as inorganic fertilizer by incineration method and as organic fertilizer directly thrown back and mulched in the field [11]. Every 5 tonnes of EFB produces one tonne of pulp [12].

Cellulose and hemicelluloses can be extracted from the EFB fibers and the wall of oil palm trunk fibers by using solvent such as NaOH with 2% H_3BO_3 under different time intervals. The hemicelluloses in the cell walls of palm EFB has a higher degree of polymerization than the hemicelluloses in the cell walls of palm trunk fiber as indicated by the molecular average weights, ranging from 7,200 to 22,900 in the former, as compared to 6,600 to 17,400 in the latter [13]. EFB vascular strands contain 70% holocellulose and 17.2% Klason lignin. Chemical composition studies on oil palm trunk and EFB fiber suggest resemblance to the grasses and cereal straws in their polysaccharide composition except for the higher lignin and lower ash content [14]. Leaf cell wall of oil palm contains moderate amount of crystalline cellulose. The major polysaccharides are acetylated arabinoxylans as in the Gramineae. Based on ^{13}C-NMR spectroscopy, the major monosaccharide residues present in the oil palm trunk are glucose and xylose. This suggests that cellulose and xylans are the predominant polysaccharides in the cell wall of palm trunks [15]. Lignin is phenolic polymeric complex molecule that attaches to cellulose and hemicellulose, through H-bonding and other ether linkage to make polysaccharide chain stiff and rigid.

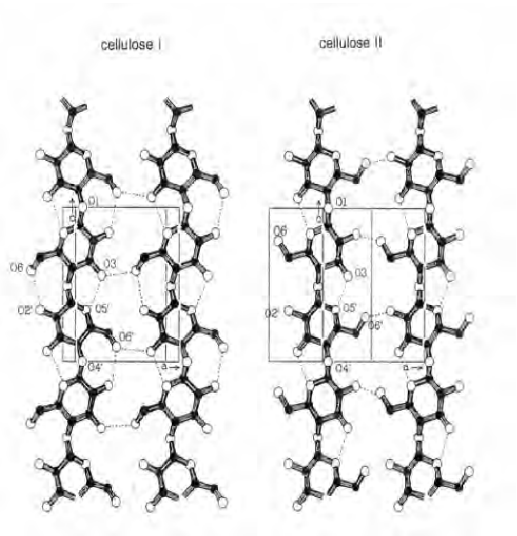

Figure 1: Cellulose polymers [15]

Cellulose is a linear polymer of anhydroglucose units linked together with β-1,4-glucosidic bond. Two adjacent glucose units are linked by the elimination of one molecule of water between their hydroxyl group at carbon 1 and 4.

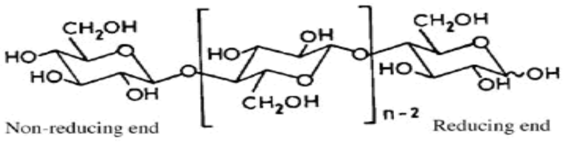

Figure 2: Anhydroglucose unit [16]

Three hydroxyl group of anhydroglucose are able to interact and form hydrogen bond by means of intra and inter molecular interaction. The strength of this hydrogen bond is around 25 KJ/Mol (Van der Waal force 0.15 KJ/Mol; O-H Covalent bond 460 KJ/Mol). From infrared spectroscopy, X-ray diffraction and nuclear magnetic resonance (NMR) investigations, it is shown that intermolecular hydrogen bonding between O-3-H and O-5 of adjacent unit; assume the existence of a second intermolecular hydrogen bond between O-2-H and O-6.

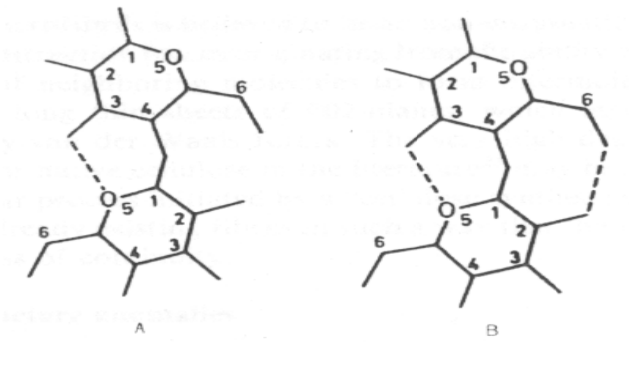

Figure 3: A) Intra and B) Intermolecular interactions [16]

In most natural fibers, the microfibrils orient themselves at an angle to the fiber axis called the “microfibril angle”. It will give information about the elastic, creep and strength properties of wood sample. Microfibers have been manufactured from dissolved cellulose, from which threads, yarns and fabrics can be made. These cellulosic microfibers may be used to produce fabrics with very soft feel that is characteristic of microfiber fabrics, and water absorbency and comfort of cellulosic fabrics. These fabrics have exceptional abilities to remove dust and oil droplets from surfaces and gas streams, and are useful in filter media. In a spherical cellulose material where the cellulose material is a water-insoluble polysaccharide formed by β-1,4-type sugar linkages, the degree of crystallinity is 70% or greater, and macrofibrils are formed radially from the center to the periphery [16]. The dissolution of cellulose in selective solvent has been described as a very recent subject for direct dissolution and regeneration of cellulose fiber.

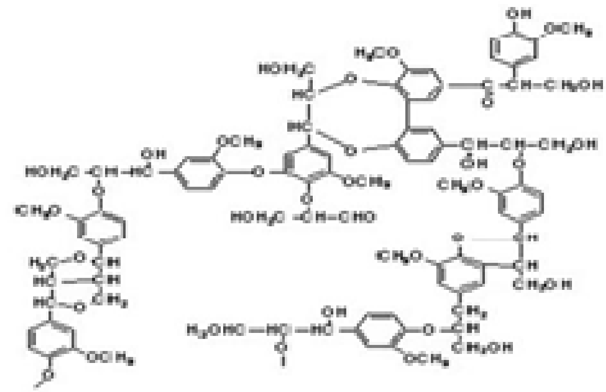

Figure 4: Structure of Lignin [25]

III. DISCUSSION

The large-scale plantation of Oil Palm in Malaysia has resulted in huge production of EFBs. From one tonne of palm oil produced, 220Kg of EFB generated, and annual production of EFBs stands high at 2.8 to 3 million tonnes. The composition of EFB includes water 58%, nitrogen 0.80%, phosphorous 0.06%, K 0.24%, Mg 0.18% on fresh weight basis [17]. This percentage may vary with the variation of one or multiple growth factors, climatic changes, soil fertility, fertilizer utilization and other management practices. The presence of inorganic components in the EFB such as nitrogen, phosphorous, potassium and magnesium enable its utilization as fertilizer. Phosphorous, potassium and nitrogen (PKN) are the good fertilizer as required for the proper growth of plants. EFB has the potential to reduce or replace the need of fertilizer at the amount 4.4 kg of Kieserite, 19.3 kg of Muriate, 2.8 kg of rock phosphate and 7 kg of urea per one tonne of EFB mulch in agro field [18].

EFB also has the potential as a source of lignin for the production of ethanol. The ethanol production from EFB by countries like Malaysia and Indonesia may have to meet the 1-2% utilization of gasoline with 15.88 Million tonnes of crude palm oil and total production of EFB estimated at 6.19 Million tonnes. The estimated availability of 3.72 million tonnes of EFB would have potential for 0.30 Million kL of ethanol production [19].

Many composite materials have been synthesized and studied for their potential uses. A study on the synthesis of composite material, the EFB pulp as the reinforced agent in polypropylene (PP) composite, has reported material with high tensile and flexural properties. The EFB obtained by basic (NaOH) pulping may increase its crystallinity and enhances the interaction with the polypropylene (PP), resulting in high strength of lignocellulosic composite [20].

High quality Briquette fuel is produced by the mixing of 100% pulverized Empty Fruit Bunch (EFB) with sawdust or Palm kernel expeller (PKE) [21]. Hybrid Composites of EFB prepared with jute have high tensile properties and hydrophobicity as compared to pure EFB composite. EFB-Jute composites have higher density of 1.2 g/cm^3 that improve the tensile property and reinforcement of composite [22]. In composite material, most of lignocelluloses is used as filler in thermoplastic matrix. EFB-Benzoylated composite exhibits enhanced tensile properties due to interaction and adhesion with the polymer matrix [23].

Lignocellulosic fibers also have the potential to replace the synthetic fibers such as aramid and glass fibers in the field of composite material. Lignocellulosic fibers have low density (1.25-1.50 g/cm^3) as compared to the fiber glass (2.6 g/cm3), but have high tensile strength as in plastic materials, environmentally friendly and easy to handle as compared to the synthetic Glass fibers. Cutting, mounting and other operational processes may lead to more severe health problems for the workers, including skin and respiratory diseases, but lignocellulosic fibers are safer. These fibers can be thermal insulators and easily recyclable and biodegradable.

Pharmaceutical grade lignocellulosic fiber can also be synthesized. the typical tendon ligament fibers of joint are shown in Figure 5. The lignocellulosic composite fiber may be used for the replacement of bone ligament.

Figure 5: Tendon Ligament Fibers [24]

Lignocellulose composite material of desired use would have the strength of 28-40 MPa and the strain of 20-30% at body temperature in high moisture content [24]. Malaysian Oil Palm agro-wastes have very good potential application as untreated (fuel, fertilizer) or treated materials (pulp and paper, composites used for mechanical purposes) and materials with high purity of the Health grade (ligament replacement fibers).

IV. CONCLUSION

In this study, the potential development of Oil Palm Agro Waste value added bio-materials is discussed. EFB utilization has applications as fertilizer, fuel and synthesis of high tensile composite materials for mechanical and pharmaceutical grade. This may be of great interest to existing oil palm mill as a new economic model.

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