CHEMICAL THERMO-MECHANICAL PROCESS (CTMP) FOR THE PRODUCTION OF CELLULOSE-PULP FROM OIL PALM BIOMASS

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699

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Oil palm empty fruit bunch (EFB) contains about 70%-80% holocellulose; which comprises about 40%-45% and 30%-35% of cellulose and hemicelluloses respectively; and 18%-22% lignin. Cellulose is a polymer of α-D-1,4-linked anhydrous glucose units, $(C_6H_{12}O_5)_n$. Basically, the individual cellulose molecules are linked together to form elementary microfibrils, which, in turn are aggregated by intermolecular hydrogen bonding into larger subunits called fibrils. The microfibrils contain alternating phases of highly ordered (crystalline) and randomly oriented (amorphous) cellulose embedded in a matrix of hemicellulose (Cole, 1983). This latter carbohydrate (also known as pentosan), constituting 20% - 25% of the plant dry weight, is a branched polymer of pentose sugars, $(C_5H_{10}O_4)$n. The cellulose and hemicelluloses are bonded with the matrix of lignin, and this lignin has to be removed in order to get high cellulose content of pulp.

The cellulose pulp can be a resource for the manufacturing of pure cellulose and cellulose derivatives, glucose for fine chemicals and nano-cellulose. Chemical thermo-mechanical process (CTMP) is a well-known process in the production of pulp and paper, and it is also known as mechanical defibrillation. Sodium hydroxide (NaOH) is normally used as an intra-crystalline swelling agent for both the crystalline and amorphous cellulose (Zhang *et al*., 2012). Hong *et al*. (2013) found that two hydrolysis steps using mild acid and NaOH delignification process increased the digestibility of the EFB fibres up to 76.9%. Another study used the steam generated from the palm oil mill boiler (0.28 MPa and 140^{o}C) to treat the fibre, hence enhancing the fibre's accessibility towards enzymatic conversion into sugars up to 30% (0.209 g g^{-1} EFB) (Syamsudin *et al.*, 2012). The lignin is dissolved in the waste water in the form of black liquor.

In this technology, an integrated system is introduced in which the EFB fibres will first be treated with NaOH solution before processing it using thermo-mechanical refining. The lignin part of the EFB will be dissolved in the NaOH solution to form a waste water called black liquor. For the production of cellulose pulp, the treated EFB fibres will then proceed to the bleaching process using sodium chlorite and acetic acid. The advantage of this integrated system is that minimal amount of bleaching chemical is used in the treatment, and the acidic waste water from this stage can be mixed with the black liquor from the earlier NaOH treatment. This mixture will neutralise the waste water, and simultaneously the lignin will be precipitated. This could reduce the cost of waste water treatment and creates additional income from the sales of lignin.

THE PROCESS

The process involved thermo-mechanical process of EFB after the treatment using 20% NaOH (pre-soaked overnight) and the optimum digestion and refining parameters are 200 s and 160^{o}C respectively. The CTMP fractionation process would simultaneously remove the lignin and disintegrate the microfibrils of the fibres, hence increasing the surface area of the fibres for the enzymatic saccharification. The refiner/digestion system consists of a digester and 63.5 cm (12 in) refining plate which runs under continuous pressure. The raw materials are fed into a pressure vessel via life bottom bin (LBB). From the LBB the material then passes into the 2.6 m long cooker or inclined digester and into a reaction vessel. After the digestion is completed, the material is fed via a screw conveyor to the centre of the refiner. The operating parameters for the refiner are the pressure (up to 8 bar) and the speed (up to 3000 rpm). The required pressure is maintained by a constant supply of steam from a steam generator. The speed of the screw conveyor especially digester is adjustable depending on the different holding time and cooking time required before the refining process takes place.

The refined fibres are then washed with mild acetic acid to neutralise the pH, before being treated with an optimal amount of sodium chlorite to get the cellulose pulp.

THE PRODUCT

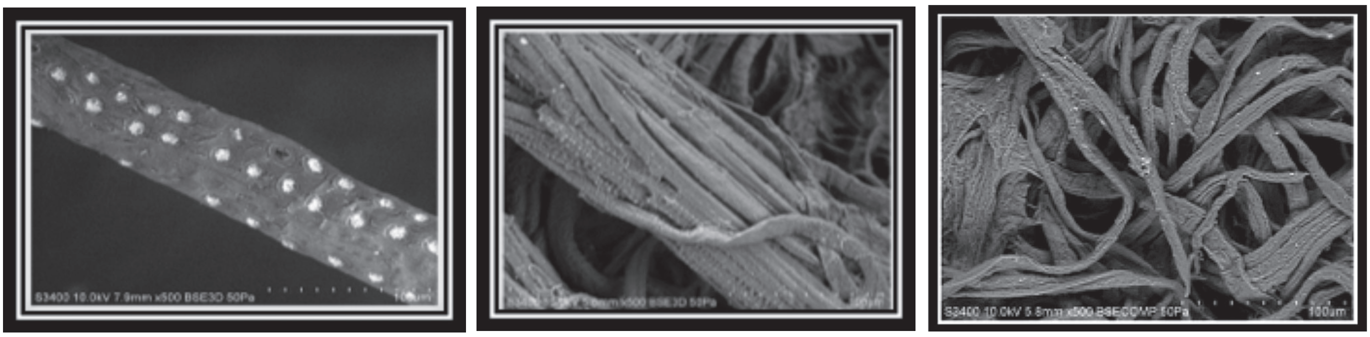
The yield of cellulose-pulp from EFB is >70% (based on dry weight of EFB). Analysis on the accessibility of the cellulose pulp towards the enzymatic hydrolysis (cellulase and cellobiase enzymes) has shown that the treated EFB fibres gave high total sugars yield.

The SEM analysis has shown the disintegration of the EFB fibres with the process, which thus has enhanced the accessibility of the fibres (*Figure 1*).

This technology has been tested in the MPOB Pilot Plant, in which the digester/refiner system can be operated at a capacity of 40-60 kg hr^{-1} (*Figure 2*).

TABLE 1. SUGARS YIELD FROM THE ENZYMATIC HYDROLYSIS OF EFB FIBRES

No.	Treatment	Sugars concentration (g $litre^{-1}$)		
		Glucose	Xylose	Total sugars
1.	Untreated	2.50	5.33	7.83
2.	CTMP treated fibres	18.01	8.28	26.29
3.	Cellulose pulp from CTMP treated fibres	31.87	13.23	45.10



(a) (b) (c)

Figure 1. The SEM analysis of the fibres: (a) untreated EFB, (b) EFB fibres treated with 20% NaOH, (c) EFB fibres treated with 20% and bleached with sodium chlorite and acetic acid. (Magnification 500X.)

Figure 2. The soaking and the CTMP processes in MPOB Pilot Plant.

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