The Potential of Oil Palm Leaf Fibre in Paper-making Industry

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Abstract. Utilization of agro-based fibre for paper making has been the subject of interest in order to expand the usage of renewable resources as well as reduced the dependence on wood pulp. As one of the major countries in palm oil production, some of the waste from the oil palm plantation like the oil palm fronds, empty fruit bunches, and its leaf is a potential source of non-wood industry which can be used as raw material in the paper industry manufacture. This study was done to examine the potential of palm leaves to be used as a raw material of non-wood resources in the papermaking industry. In this study, sodium hydroxide (NaOH) pulping and process was employed to investigate the effectiveness of lignin removal for good fibre production. The concentration of the pulping agent was fixed at 7% at treatment of 1-7 hours to investigate the best condition for defibrillation of the cellulose fibre. Based on this study, it was found that the soda pulping produces fibre that can be molded into paper sheet without any binding agent. The morphology of the fibre observed under Scanning Electron Microscopy (SEM) shows that, soda pulping fiber consist of individual micro fibrils that are well separated. Both tensile strength and tear index gives highest value at 1.93 kg/cm² and 37 Nm²/kg respectively at 7 hours treatment time. His reflects that lignin removal effectively occurred in soda pulping. Tensile strength found to increases with treatment time and both tensile strength and tear index of the paper falls within the value comparable to commercial non-wood paper. The paper produced has rough surface and has the potential to be develop for craft paper.

1. Introduction

Paper is a thin layer material that produced from the fiber of cellulose pulp that produced from mechanical and chemical pulping of lignocellulosic biomass which is normally used for writing, cleaning, printing and packaging. For a little more than a century, wood species have been the primary raw materials for producing cellulose pulp; in fact, 90–95% of all pulp has been obtained from such materials. World wood pulp production in 2003 amounted to 170,358,000 tons, whereas non-wood pulp production was only 18,695,000 tons [1]. The tree, as the source of paper manufacturing has been used since 200 years ago. This long term used of tree consequently increasing the area of deforestation that will contribute to global warming and other environmental problem. Due to this reasons, researchers has found other alternatives for production of lignocellulosic pulp from non-wood resources [2-3].

Agro-based fiber resources have the potential to complement conventional wood supplies because, they are abundant, have short cycles and rapid regeneration, and are of comparatively low price. Wheat
straw [4], rice straw [3], sugarcane straw [5], reeds [6], bamboo [7], bagasse [8], kenaf [9], palm oil [3] and jute [10] were among the non-wood fibre resources available for paper production.

Production of pulp from oil palm fronds has been demonstrated by [11] for papermaking. Hence, to enhance the use of the abundant biomass generated by the palm oil industry in Malaysia this study was conducted in view of exploring the papermaking potential of this industrial by product. Oil palm leaves was used in this study as it is consider as potential non-wood lignocellulosic compound for paper production since it contains 43.8% cellulose [12] within the acceptable range of wood fibre (40-45%) [13]. Meanwhile, the lignin content of oil palm leaves was reported around 19% and falls in the low range of those in wood resources (18 - 25%)[14]. Therefore, these compositions present in oil palm leave consider as suitable to be used for paper manufacturing.

In parallel with the growing scarcity of conventional raw materials, the increasing concern with the environment and its preservation have exposed the need to replace the classical pulping processes (e.g. Kraft, sulphite), which use sulphur-containing reagents of which can cause serious pollution problems upon released to the drainage. In addition, the development of new pulping processes using less polluting chemicals [3] has foster this research to adopt an eco-friendly process by using non-toxic chemical as the pulping agent.

2. Materials and Methods
The materials and methods used in this study was described in this section.

2.1. Soda Pulping
The fresh green leaves were washed to remove any unwanted residue prior to chemical pulping. After washing with the running water, the leaves were cut into smaller sizes (3 cm – 5 cm) then it was grind before soaking with sodium hydroxide (NaOH) for delignification process using 7% NaOH concentration at different treatment time with temperature around 80 °C to investigate the effectiveness of lignin removal for good fibre production as shown in Table 1. Once the delignification process was completed, the liquor was wash several time with running water and the obtained fibre was then undergoes bleaching process with 10% hydrogen peroxide (H₂O₂) for overnight. After that, the liquor was wash again with running water to removes the H₂O₂ residue. Then, the fibre obtained was dispersed in the water bath to be molded using mold and deckle. The paper was then dried in the oven until the pulp was dried.

| Sample | S1 | S3 | S5 | S7 |
|--------|----|----|----|----|
| NaOH Conc. | 7% | 7% | 7% | 7% |
| Time (h) | 1  | 3  | 5  | 7  |

2.2. Characterization of The Paper
The paper sample was undergoing fourier transform infra-red (FTIR) analysis to identify the functional groups presence in the fibre before and after treatment. FTIR was performed using Perkin Elmer Spectrum 100 FTIR Spectrometer. Then, scanning electron microscope (SEM) analysis was also done to obtain the surface morphology image of the paper. The SEM was conducted using JEOL JSM-5610LV machine. The image was captured at 100x and 500x magnification at 20kV accelerating voltage. Tensile testing and tearing resistance was done to identify the mechanical properties of the paper using GOTECH/AI-700 electronic tensile machine and DC-SLY13K tearing tester respectively.
3. Results and Discussion

3.1. Fourier Transform Infra-Red

The effect of chemical treatment on lignin removal from the palm oil leaves was investigated in this study. Lignin is usually considered as a polyphenolic material having an amorphous structure which consist of three different phenylpropane building block namely p-coumaryl, sinapyl and coniferyl as in figure 1. Paper quality is identified by the good strength, bleach ability, high cellulose and hemicellulose content and low lignin content. Therefore, it is desirable to have a pulp process that gave the highest delignification efficiency and good quality of cellulose and hemicellulose [15]. The decomposition of lignin and the appearance of cellulose peak can be detected using FTIR analysis. The effect of soda pulping on lignin removal affects the quality of the paper product. Lignin decomposition during soda pulping is usually attributed to the cleavage of the α-aryl ether bonds from its phenylpropane monomers (figure 2) at around 1100 cm$^{-1}$ and 1246 cm$^{-1}$ [5] [16-17]. Based on the ftir spectra in figure 3, as the soaking time increasing, the intensity of the ether bond decreasing as well as the peak of –OH at 3000 cm$^{-1}$. This indicate that more of the ether cleavage has occured during the pulping.

![Figure 1: Phenylpropane building block of lignin](image)

Based on the FTIR analysis, it was concluded that soda pulping removes lignin effectively after 7 hours of soaking due to low lignin content of oil palm leave. When the pulp was molded, it forms a sheet of paper after drying without any binding agent with rough surface (figure 4). This is closely related to the chemical composition of the fibre. Lignin and cellulose content in the fibre strongly affect the suitability of the non-wood fibre for paper production apart from its fibre dimension [18].

![Figure 2: The mechanisme of α-ether cleavage at phenylpropane unit during delignification](image)
3.2. Surface Morphology
The SEM image of the fibre (figure 4) shows that the fibrillar structure clearly observed after removal of lignin [19] and it increase the mechanical interlocking at the interface that makes the fibre mouldable into a sheet of paper without any processing aid. As the treatment time has been prolonged, the fibre become curly and soft upon alkali treatment and the fibre bundle being oriented in various orientations in the paper sheet. Separation of fibre bundle into elementary fibre was also observed with increasing treatment time as shown in Figure 5 where at 7 hours alkali treatment, more elementary fibre was distributed in the paper. The SEM image of this oil palm leaf paper compared to hard wood paper for newsprint purpose (figure 6) shows that the fibre oriented in similar manner. However, the presence of voids are not really significant in hard wood paper due to the presence of processing aid like filler to increase smoothness and opacity [20]. With advance processing method, the oil palm leaf paper can be competitive to commercial hard wood paper.
**Figure 5**: SEM image of oil palm leaf paper treated under different soaking time.
Figure 6 : SEM image of hard wood paper for newsprint purpose [20]

3.3. Mechanical Strength
The tensile strength of the paper are comparable to other agro-based paper like pineapple leaf [21] but lower than wood paper probably due to weak fibre bonding and fibre strength [14]. The tensile strength of a paper highly influences by the arrangement of the fibre in the paper. As in this study, the handmade technique during the molding step affects the non-uniformity on the orientation of the fibre and it might give low value of tensile index. Meanwhile, the tear index of the paper were in the range of commercial paper tear index [22] and showed the increasing value as the soaking time increase. This might be due to hydrogen bonding interaction among the cellulose material [23] and hence increase the strength of the paper sheet.

Table 2 : Tensile strength and tearing force of oil palm leaf paper

| Sample | Tensile Strength (kg/cm²) | Tear Index (Nm²/kg) |
|--------|----------------------------|---------------------|
| S1     | 0.50                       | 15.85               |
| S3     | 0.40                       | 37.26               |
| S5     | 0.40                       | 27.12               |
| S7     | 1.93                       | 36.69               |

4. Conclusion
This study shows that the soda pulping treatment at 7% concentration starting at 1 hours found to be able to removes the lignin from the oil palm leaf. At this concentration, as the treatment time increase, the tensile strength and tear strength is increasing. Without the addition of processing aid like binding agent, the pulp obtained can be mold into a paper sheet and this proves that agro-waste fibre has huge potential to be developed for paper making application. However, further experiments should be conducted in the application part in order to suggest the most suitable range of paper derived from oil palm leaf pulp.

5. References
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