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Chemical pulping of waste pineapple leaves fiber for kraft paper production

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ABSTRACT

The main objective of this study is to evaluate the implementation of acetone as a pulping agent for pineapple leaves. Mixtures of water and acetone with concentration of 1%, 3%, 5%, 7%, and 10% were used. The effects of soaking and delignification time on the paper properties were investigated. Thermal and physical properties of paper sheet were studied using thermogravimetric analysis (TGA) and tearing resistance test respectively. The morphological properties were observed using microscope at 200× magnification. The paper sheet produced from pulping with 3% acetone concentration shows the highest mechanical properties. Papers strength was improved by increasing the delignification time. The delignification time was reduced by cooking the pineapple leaves at a temperature of 118 °C under applied pressure of 80 kPa which has remarkable effect on paper strength.

1. Introduction

Pulp and paper industries have been considered the main consumers of natural resources (wood) and energy (electricity), including water, and significant contributors of pollutant discharges to the environment. The demand for paper and the unacceptable large ecological footprint of current paper production requires the need for alternatives. It was reported in 2004 that the annual paper consumption is 52.45 kg per person and was 16.32% greater than in 1991. The use of printing and writing paper grew by more than 10% from 1980 to 2000 [1]. In many parts of the world, local supplies of wood cannot support the demand for pulp. As a result, the search for non-wood raw materials in papermaking industry has been given more attention due to the rising consumption of wood resource for the paper production. From 1970 to present time, the non-wood plant fiber pulping capacity has increased on a global basis two to three times as fast as the wood pulping capacity. It was also forecasted that during the next decade, the non-wood pulp production will annually grow at an average of 6%, which is three times as fast as the production of pulp on wood basis [2]. Initially, non-wood fiber pulping occurred in regions where wood supply had been reduced to levels insufficient to sustain papermaking, and an alternative source of fiber feedstock was mandatory. Non-wood fiber resources have the potential to complement conventional wood supplies. This is because, they are abundant, have short cycles

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and rapid regeneration, and are of comparatively low price. Therefore, non-wood fiber will play important roles in papermaking as substitutes or complements to wood. Examples of non-wood fiber resources available for paper production are wheat-straw [3–5], rice-straw [6,7], sugarcane straw [8], reeds [9], bamboo [10], bagasse [11,12], kenaf [13], palm oil [14], and jute [15]. Non-wood material, particularly wheat straw, was successfully exploited as the main raw material for papermaking in China because of the limited wood resource with forest coverage of only 13.94% [16]. By a wide margin, the leading non-wood plant fiber presently in use is straw, followed by bagasse and bamboo. However, pineapple leaf fiber (PALF) is another alternative non-wood fiber that can be used for paper production. There have been numerous studies carried out by researchers on various aspects of PALF. PALF obtained from plants bearing edible fruits were examined for textile purposes, and blends of PALF with silk and polyester fibers were studied [17]. PALF have also been incorporated into thermoplastic materials such as polypropylene and polyethylene to produce biocomposite materials. The use of non-wood raw materials provides several interesting advantages; specifically, it allows wood raw materials to be saved for other more decent uses and hence deforestation and replanting to be alleviated. It can also reduce wood and cellulose fiber imports in countries with a shortage of wood raw materials. Besides, users are increasingly demanding papers that are obtained by using clean technologies or made from recycled or non-wood fiber. The current challenges of the pulp and paper industry are the achievement of affordable quality pulp while preserving the environment by using increasingly smaller amounts of water and energy and gradually fewer raw materials [4]. It is also important to minimize pollution from residual effluents that results from cooking and bleaching of the raw materials. The increasing concern with the environment and its preservation have exposed the need to replace the classical pulping process such as kraft and sulfite pulping which use sulfur containing reagents. This is due to the fact that the release of sulfur to the environment can cause serious pollution problem [6]. The new pulping processes using less polluting chemicals known as the "organosolv" processes have been developed by the researchers to resolve the problem. During the last years, this large progress of process technology has been reported to reduce the sulfur emissions by the pulp mills. Even though the ability to obtain pulp by using the organic solvents has been known for some time, pilot plants and small-scale industrial plants exploiting them have only recently come into operation. This has been the result of the shortage of alternatives to traditional procedures, which leads to the expenditure of substantial efforts in new processes. In fact, some processes that use organic solvents are being reconsidered in response to the new economic and environmental order.

2. Methodology

2.1. *Raw material*

Pineapple leaves were obtained from the plantation of Malaysian Pineapple Industry Board (MPIB), Johor, Malaysia. Industrial grade acetone with 65% purity was purchased from Krass Instrument and Services.

2.2. *Sample preparation*

Dried pineapple leaves were immersed in mixtures of acetone/water of 1%, 3%, 5%, 7%, and 10% (v/v) for 3 days to study the effect of acetone concentration on paper quality and to optimize the best mixture content for farther preparation. The effect of soaking time was studied at interval times of 3, 7, 21 and 28 days. Mixture of 3% acetone was used to investigate the effect of cooking time on paper properties at 118 °C under applied pressure of 80 kPa. The pineapple leaf pulp was washed with water and disintegrated in a laboratory blender. The pulp was molded using mold and deckle. The paper was dried in the oven at 60 °C until the pulp was fully dried. Finally, the paper was pressed using the compression molding machine at 100 °C and pressure of 10 MPa to get even thickness of paper sheet.

2.3. *Testing*

The turbidity of spent liquor from puling process was determined using HACH Ratio/XR Turbidimeter. Thermogravimetric analysis (TGA) was performed by using Mettler Toledo TGA/STDA851 at heating rate 10 °C/min with the temperature range between 30 °C and 800 °C. TGA was used to determine the thermal stability of cellulose and lignin in pineapple leaves and the paper sheet. The tearing resistance test or Elmendorf tear test was used to measure the internal tearing resistance of the paper rather than the edge-tear strength of paper. The test was carried out according to ASTM D1922 using the HT-8181 Elmendorf Tearing Strength Tester. The tearing resistance (expressed in grams-force, gf) of the paper was determined from the average tearing force and the number of sheets comprising the test piece using following equation:

$$\text{Tearing resistance, gf} = \frac{16 * 9.81 * \text{average scale reading} * \text{gf capacity}}{n * 1600\,\text{gf}}$$

where gf capacity = 3200 g and number of plies, $n = 1$.

Inverted Microscope LEICA DMIRM equipped with a digital camera was used to study the morphology of the paper at 200× magnification. Morphological study was used to observe the fibers structure and their coarseness in the paper.

3. Results and discussion

3.1. *Turbidity*

Pulp 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 [18]. The effect of acetone concentration on the pineapple leaves pulping was first observed by the turbidity of the spent liquor after the pulping process. In organic solvent pulping process, the removal of lignin