Production and Characterization of Paper from Pineapple Leaves and Sugarcane Bagasse Pulp

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Abstract. Paper is the final product resulted from compression of fiber suspension of cellulose pulp, which is derived from wood or non-woody material. In this study, paper was made from mixture of pineapple leaves and sugarcane bagasse pulp (P:S, 100:0%, 80:20%, 60:40%, 40:60%, 20:80%, and 0:100%) at varying cooking liquor or NaOH concentration (1.5% and 3%) using semi-mechanical soda pulping method. Pulp characterisation (kappa number, tensile and tearing strength) was further carried out to ensure a stable pulp and paper quality. Results showed that the highest tensile strength of 6,709 kN was obtained at pineapple leaves and sugarcane bagasse pulp composition of 100:0% and NaOH 3%, whereas the highest tearing strength (1730, 13 mN) was observed at the P:S of 40:60% with similar concentration of NaOH. The lowest kappa number (6,182) was also obtained at P:S of 0:100% and 3% NaOH. The pulp characterisation values have fullfil SNI No. 6519:2016 quality standard for plastic laminated paper.

1. Introduction

Paper can be made from raw materials containing originally from wood fibers due to abundant availability of these materials in the forest [1]. Nowadays, it also can be made from non-woody raw materials such as hemp, sisal, abaca, jute, flax, and so on [2]. According to Ministry of Industry of Indonesia [3], pulp and paper production have reached 4,55 million and 7,98 million for pulp and paper, respectively. This number ranked the country ninth in pulp production and sixth in paper production among the world’s 10 largest manufacturing countries in the world. Pulp and Paper Association of Indonesia estimated that the pulp and production may reach 20,4 million tonne/yr and 19,8 million tonne/yr in 2020. The target is to fulfil increasing world paper demand which increases 0,5% annually until 2020 [1]. Increases in the demand inevitably increasing consumption of the wood materials. Continuous deforestation for manufacturing will have negative impacts on the environment, for example flooding and global warming, therefore there is a need to find alternative raw materials to replace wood as the raw materials for pulp and paper manufacturing.

Pineapple or Ananas Cosmosus (family Bromeliaceae) is generally a seasonal type of plant and found for the first time growing in tropical areas of South America, mostly Brazil. Nuryati [4] showed that pineapple production increased 2,42% per year in Java island, whereas it increased by 6,75% in average per year outside Java island between 2011 and 2016. Pineapple leaves have outside layer which consist of top and bottom layer. There are a lot of bundles of fibers among the layer that are bonded or coated one to each other with some kind of leaf adhesive. About 2.5 to 3,5% pineapple leaf
fibers are resulted from fresh leaf weight mass [5]. Furthermore, pineapple leaf contains 69.5-71.5% of alpha cellulose, rendering them good for its use in pulp making.

Another non-woody material which can be used for pulp making is sugarcane bagasse, which abundant in Indonesia. Post harvesting and agricultural products activities have not been optimized in utilizing this by-product material. According to Yudo and Jatmiko [6], the sugarcane bagasse produced could reach 90% from every processed sugarcane. Sugarcane bagasse mostly contains lignocellulose, with cellulose content of 37%. Thus not only making the bagasse potentials as pulp raw material, but also in reducing wastes resulted from sugar manufacturing. The length of fiber is between 1.7-2.0 mm with a diameter around 20 µm, thus it meets requirements for production of paper board.

Several research has been done to produce pulp and paper from non-woody materials, individually or in combination of the materials and or processes. To the best author knowledge, none has investigated its manufacturing from combination of pineapple leaves and sugarcane bagasse. Mufridayati et al. [7] studied combination of crested pineapple and rice straw fibers (100:0%, 80:20%, 60:40%, 40:60%, 20:80%, and 0:100%) using concentration of cooking liquor or NaOH of 1.5% at 100°C for 1.5 hrs. These authors’ results showed that the 40:60% was the best ratio, with tensile strength of 16,945 Nm/g and tearing strength of 3,719 x 10³ Nm²/g which followed SNI 14-1308-1998. Ayunda [7] investigated the pulp and paper making utilizing pineapple leaves and water hyacinth with similar processing conditions and variables as Mufridayati et al. [8]. These authors obtained 60:40% as the best ratio, with gramatur of 71.23 gr.m⁻² and tearing strength of 90,5974 mN (SNI 14-0115-1998).

Based on these previous investigators, then pulp and paper production was carried out in this study, and the objectives were: (i) to produce pulp and paper by varying composition of pineapple leaves and sugarcane bagasse and to determine the best ratio; and (ii) to analyze the pulp and paper produced by common indicators namely kappa number, tensile strength and tearing strength.

2. Methodology

2.1. Raw materials and preparation
Pineapple leaves and and sugarcane bagasse were obtained from traditional market. These raw materials were cut into a length of 1-2 cm, which then further dried approximately nine hours each day under sunlight for three days’ period to reduce its water content.

2.2. Pulping processes and pulp mixing
A 20-L pot was filled with 500 g of cut and dried sugarcane bagasse. Next, previously prepared cooking liquor (NaOH 1.5% w/v, 7500 mL) was added into the pot, followed by cooking for 1.5 hrs at 100±5°C. Similar treatment was done for 3%w/v NaOH cooking liquor. Temperature was maintained during the pulping by closing its lid tightly. The formed pulp was washed using clean water repeatedly to remove the remainder of cooking liquor and to maintain quality of the pulp (hence paper) produced. The pulp was then screen and mashed, followed by putting the pulp into a prepared mold and drying under the sunlight. Similar procedures as for sugarcane bagasse were carried out to make pulp from pineapple leaves. Paper was made by varying composition of pineapple leaves and sugarcane bagasse (100:0%, 80:20%, 60:40%, 40:60%, 20:80%, and 0:100%).

2.3. Pulp and paper analysis
Tensile strength testing (TAPPI T 494), tearing strength testing (TAPPI T 414), and kappa number analysis (TAPPI T 236) were carried out at one of the biggest Pulp and Paper Company in Pekanbaru, Riau, Indonesia.
3. Results and discussion

3.1. Influence of pineapple leaves and sugarcane bagasse composition ratio on tensile strength

Figure 1 shows the results of tensile strength of the paper produced at varying composition ratio of pineapple leaves and sugarcane bagasse pulp. Tensile strength of paper is a measure of maximum stress that a strip of paper sheet with certain dimension can handle before breaking. As can be seen from Figure 1, the values of tensile strength decreased with decreasing of the percentage of ratio of pineapple leaves pulp or increasing of the percentage of ratio of sugarcane bagasse pulp. The tensile strength values are generally higher with 3%w/v NaOH than 1.5% NaOH (around 1 kN difference prior falling at 100:0% ratio). The higher values may be explained by higher lignin contents (explained in later section), resulting in more rigid paper but reduce of inter-fiber strength bonding. Ayunda [7] also obtained similar results (higher tensile strength at higher pineapple leaves composition) by combining the pulp of pineapple leaves and water hyacinth. These results show that pineapple leaves have better physicochemical properties strength than sugarcane bagasse. According to Ek et al. [9], paper tensile strength depends on the length of fiber, the strength of fiber, specific bonding strength and bonded area. Based on Figure 1, the highest tensile strength (6,709 kN) was obtained at pineapple leaves pulp composition of 100% and NaOH cooking liquor of 3%w/v. In the contrary, the lowest tensile strength of 4,092 kN was obtained at 100% sugarcane bagasse pulp and 3%w/v NaOH. The tensile strength quality standard for plastic laminated paper according to SNI 6519:2016 is 1.63 kN, which has been met for every samples tested in this study.

![Figure 1. Effect of pineapple leaves and sugarcane bagasse percentage ratio on the paper tensile strength (P: pineapple leaves; S: sugarcane bagasse).](image)

3.2. Influence of pineapple leaves and sugarcane bagasse ratio on tearing strength

The results of tearing strength of the paper produced at varying composition ratio of pineapple leaves and sugarcane bagasse pulp is illustrated in Figure 2. Tearing strength is a measure of paper resistance to the force (in gf or mN) needed to tear paper in standard conditions. According to Figure 2, it can be seen that tearing strength results decreased with increasing sugarcane bagasse composition at 1.5%w/v NaOH. However, a reverse effect was observed with 3%w/v NaOH, in which the paper tearing strength increased with increasing sugarcane bagasse composition until the pulp (P:S) composition ratio of 40:60% although followed by decreasing in the values at 20:80% and 0:100% composition ratio. It was hypothesized that the behaviour of tearing strength similar to the results obtained with tensile strength in Figure 1, which showed decreasing values of the tensile strength with the addition...
of sugarcane bagasse. These results may be due to inhomogeneous distribution of pineapple leaves and sugarcane bagasse pulp observed, thus affecting the fluctuation in the tearing strength values.

The values of tearing strength with 3%w/v NaOH were always higher than 1.5%w/v NaOH as the cooking liquor at any composition ratio. This may be explained by the higher lignin (Section 3.3), which were not fully degraded utilising 1.5%w/v NaOH. According to Tobing [10], lignin is a hard, stick, and rigid substance, causing low tearing strength values. Pulp that has good strength contains low lignin content [11]. The highest tearing strength value i.e. 1730.125 mN, was obtained at ratio of pineapple leaves and sugarcane bagasse pulp of 40:60% and 3%w/v NaOH, whereas the lowest value (496.75 mN) was observed at the ratio of 0:100% and 1.5%w/v NaOH. The tearing strength results obtained in this study have fulfilled the requirements of SNI 6519:2016 for plastic laminated paper.

![Figure 2. Effect of pineapple leaves and sugarcane bagasse percentage ratio on the paper tearing strength (P: pineapple leaves; S: sugarcane bagasse).](image)

### 3.3. Influence of pineapple leaves and sugarcane bagasse ratio on kappa number

Figure 3 shows the results of kappa number values at varying composition ratio of pineapple leaves and sugarcane bagasse pulp. Kappa number indicates the lignin content contained in the pulp. Its analysis was purposed to find out how much degree of delignification occurred after cooking and amount bleaching liquor needed in bleaching stage.

The variation of cooking liquor affected the kappa numbers in each sample. The resulting kappa number values were higher for 1.5%w/v NaOH than 3%w/v NaOH. This indicates that less lignin degraded with less concentration of NaOH. Kappa numbers decreased with increasing sugarcane bagasse percentage, which could be due to sugarcane bagasse contains less lignin than pineapple leaves. This can be observed by visual analysis of the paper produced, which was brighter at higher composition of sugarcane bagasse. According to Saleh et al. [11], lignin causes pulp with dark color. The lowest kappa number value (6.182) was obtained at P:S of 0:100% composition and 3%w/v NaOH, whereas the highest kappa number was obtained with 100:0% mixture of pineapple leaves and sugarcane bagasse pulp and 1.5%w/v NaOH i.e. 35.590.
Figure 3. Effect of pineapple leaves and sugarcane bagasse percentage ratio on the kappa number values (P: pineapple leaves; S: sugarcane bagasse).

4. Conclusion
The results obtained in this study showed that plastic laminated paper can be made from mixture of pineapple leaves and sugarcane bagasse pulp utilising semi-mechanical soda method. The highest tensile strength value of 6.709 kN was obtained at pineapple leaves and sugarcane bagasse pulp (P:S) composition of 100:0% and 3%w/v NaOH. The highest tearing strength value of 1730.125 mN was obtained at P:S of 40:60%, also at 3%w/v NaOH. The lowest kappa number value (6.182) was observed at P:S of 0:100% composition and 3%w/v NaOH. The plastic laminated paper has fulfilled SNI 6519:2016 standards for minimum tensile strength (1.63 kN) and tearing strength (392 mN).

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