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Paper Bag Production using Banana Stem Via Kraft Pulping Process

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Abstract: The banana plant supplies us with numerous polymers such as cellulose, hemicellulose, pectin, and lignin, which offer fibres with high mechanical qualities in addition to the abundant nutrient-rich bananas. Recently, the planting of banana trees is increasing which lead to an increase in the waste disposal of banana stems. Banana is an annual crop and it generates a huge quantity of fibrous material as waste from its leaves and stem; for every 60 kg of banana grown, 200 kg of the waste stem is generated. This project aims to produce paper by using the banana stem as non-wood raw material by using the kraft pulping method. Banana stem from jackfruit banana tree, kapas banana tree and nipah banana tree were obtained from banana farm around Kampung Parit Besar, Muar, Johor. The stem from each aforementioned banana tree is the main materials in this project to produce paper by the kraft pulping method as mentioned and finally analysed in term of absorbency, ash content and moisture content. The findings of this project can be seen from the two phases of an experiment conducted where the papers from the respective phases differ from the other. The differences detected in the first phase are the papers are thick, hard and have a rough surface while in the second phase, the papers are thinner, softer and have smoother surfaces. To conclude the best paper produced compared to the standard used is Kapas B which was produced in the second phase of production. Kapas B is the best overall as it conquers ash content and moisture content analysis while also being the third best in terms of absorbency which is not that far from the standard. The suggestion on the best amount of pulp to be used is 25-30g.

Keywords: Non-wood, Banana stem, Kraft pulping

1. Introduction

The banana plant is, in fact, a high herb that grows two to eight meters long with leaves of 3.5 m in length. Banana trees come in a variety of sizes, colours, and flavours, depending on the size, colour, and flavour of the bananas they produce. The banana plant supplies us with numerous polymers such as cellulose, hemicellulose, pectin, and lignin, which offer fibres with high mechanical qualities in addition to the abundant nutrient-rich bananas [1].

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Recently, the planting of banana trees is increasing which lead to the an increase in the waste disposal of banana stems. Banana is an annual crop and it generates a huge quantity of fibrous material as waste from its leaves and stem; for every 60 kg of banana grown, 200 kg of the waste stem is generated [2]. The banana was used as a source of cellulose because it represents 40% of world trade fruit, has a high rate of production, is produced annually, and only 12% by weight of the plant is consumed [3]. As an alternative, paper production using banana stems is proven to yield economic and environmental bonuses [1]. Pulping and paper-making potential of the banana plant was studied by Fernandes [4] which shows its suitability for paper-making [5]. Its suitability has also been investigated using various pulping chemicals such as calcium oxide, sodium hypochlorite, hydrogen peroxide, formic acid, acetic acid, sodium hydroxide, sodium sulfide and anthraquinone [2].

This project aims to produce paper by using the banana stem as non-wood raw material by using the kraft pulping method. Therefore, we identified the percentage of pulp that can be produced from one-kilogram of banana stem. Other than that, the quality of paper produced was compared by using three different banana stems in aspects of absorbency, moisture content and ash content.

Initially, the expected outcomes of this project are the paper can be successfully produced from all three types of banana stem and the papers can be made into kraft paper bags. Furthermore, the pulps yield from each type of banana stem can be smoothly prepared. Besides that, the different types of the banana stem will give out comparable results in aspects such as of absorbency, moisture content and ash content. Lastly, the banana stem can be a stable raw material for the pulp and paper industry in paper making process to meet the demand for paper in the world economically.

2. Materials and Methods

2.1 Materials and Instruments

In this project, the materials used were banana stem and banana fibre obtained from a farm in Muar, Johor as the main materials. Besides that, sodium hydroxide, NaOH and sodium sulphate anhydrous, Na_2SO_4 (white liquor) were used. For the instruments, Hot plates as well as 2L and 1L beakers, were involved. On the other hand, the samples paper were analyzed by using drying oven, furnace and analytical balance.

2.2 Methods

2.2.1 Kraft Pulping Process

First, the outer strip of the layer was removed from the banana stem to produce banana fiber. Then, the fibers were placed in the sunlight and allowed to dry. After the fibers were dried up, they were cut into small pieces using scissors. After that, 50g of the fibers were weighed and prepared for cooking.

Sodium hydroxide, NaOH and sodium sulphate anhydrous, Na_2SO_4 (white liquor) in a 2:5 ratio were added to the fibers and prepared for cooking. Next, a setting of 3-4 was adjusted on the hot plate for the level of temperature. Thereafter, the fiber was cooked in the white liquor for approximately 2 hours. After that, the boiled mixture was set aside to cool for about an hour.

The cooked fibers were carefully filtered using a fine mesh. After filtration, the left one was a brownie cooked fiber (pulp with residual lignin). Then, the brownie cooked fiber was thoroughly washed with water for about 40 min to remove black liquor (sodium lignite) and excess alkali.

The fibers were blended so as to achieve a pulpy consistency. The pulp was poured through a fine mesh and prepared for rinsing. The pulp was rinsed thoroughly to remove NaOH and Na_2SO_4 residue. The residual of lignins were eliminated (shown in the presence of brown color solution).Then, the cooked fibers were rinsed again to remove excess lignins.

2.2.2 Papermaking Process

In the first phase, 40 g of the pulp was weighed and prepared for papermaking. Water and the pulp were added to the blender. The pulp was blended to separate the fibers in the solution. After that, the pulp mixture was poured into a silk screen in a tub 2/3 filled with water. The pulp was stirred using fingers to spread the fibres.

Then, the silkscreen was removed from the tub and the water was allowed to drain completely. Once it is done, the pulp was placed on a pellon or felt material and was pressed to remove excess water. Thereafter, the pellon or felt material was removed and the semi-dried pulp was transferred to a whiteboard to let dry in the sunlight. Lastly, the dried paper was peeled from the drying board.

Due to the unsatisfying condition of the paper produced in the first phase, the second phase of the papermaking process was conducted by redoing all of the steps mentioned above but changing the weighed pulp from 40 g to 20 g.

2.3 Paper Evaluation

In order to evaluate the papers in more detail, a sample from the commercial paper bag was used as a standard for comparison. Therefore, all samples from the papers produced in this project as well as the sample from the commercial paper bag underwent the analysis procedures.

2.3.1 Absorbency Analysis

A sample in the shape of paper strips with the dimension of 10 cm x 2.5 cm was taken from each of the paper produced. Then, the dry paper strips were weighed using the analytical balance and the data obtained was recorded. After that, the paper strips were immersed 5 cm into a beaker filled with water for 1 minute. Once it is done, the wet paper strips were weighed.

Absorbency analysis was calculated using the following equation.

$$Mass\ of\ water\ absorbed = WW - DW \qquad \textbf{Eq. 1}$$

where WW refers to the wet weight and DW refers to dry weight.

2.3.2 Ash Content Analysis

0.5-1g of sample was placed in crucibles and heated to 550˚C for 1 hour in the furnace. The ash content was calculated as follows.

$$\%AC = 100 - \%VSC \qquad \textbf{Eq. 2}$$

$$\text{where: } \%VSC = \frac{loss\ in\ weight}{net\ dry\ weight} \times 100 \qquad \textbf{Eq. 3}$$

where VSC = Volatile Suspended Compound

2.3.3 Moisture Content Analysis

The samples were dried in an air-force drying oven at 105˚C for 1 hour. Following that, the moisture content (MC) was determined in percentages on a wet basis as follows:

$$\%MC = \frac{WW - DW}{WW} \times 100 \qquad \textbf{Eq. 4}$$

where WW refers to the wet weight of the sample while DW refers to the dry weight of the sample.

3. Results and Discussion

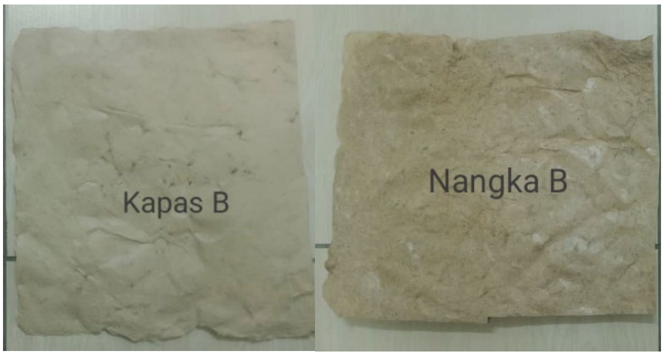
3.1 Paper

In the first phase of the production, 40g of pulp was weighed from each; kapas banana pulp, nipah banana pulp and nangka banana pulp to produce one piece of paper each. Therefore, the papers produced in this phase were labelled as kapas A, nipah A and nangka A. The papers obtained are thick, hard and have a rough surfaces. The papers obtained in the first phase were shown in **Figure 1**.

(a) (b) (c)

Figure 1: The papers produced in the first phase (a) Kapas A (b) Nipah A and (c) Nangka A

Because of that, the action of second phase production was decided to produce better papers compared to the ones from the first phase production. However, due to insufficient raw materials, only papers from the kapas banana tree and the nangka banana tree were able to be produced thus labelled as kapas B and nangka B. In the second phase of production, 20 g of pulp from each was weighed. The papers obtained are thinner, softer and have smoother surfaces. Besides that, the papers also have some small holes scattered in them. The papers obtained in the first phase were shown in **Figure 2**.



(a) (b)

Figure 2: The papers produced in the second phase (a) Kapas B and (b) Nangka B

Other than that, a sample from a commercial paper bag as shown in **Figure 3** was retrieved as a standard to compare with the results from the tests on the papers produced.

Figure 3: Commercial paper bag

3.2 Absorbency Analysis

This analysis helps to measure the amount of water the papers can absorb or resist in a set period of time specifically in this case, is for 1 minute. The water absorbency of the papers strongly influences their printability.

Table 1: Absorbency analysis on the mass of water absorbed by paper strips

Sample	Dry weight (g)	Wet weight (g)	Mass of water absorbed (g)
Commercial paper bag	0.347	0.672	0.325
Kapas A	0.751	1.869	1.118
Nipah A	0.769	1.522	0.753
Nangka A	0.630	1.163	0.533
Kapas B	0.186	0.812	0.626
Nangka B	0.294	0.849	0.555

Table 1 presents the data obtained for dry weight, wet weight and mass of water absorbed of the samples. From **Table 1**, commercial paper bag sample had a dry weight of 0.347g before the test and had a wet weight of 0.672g after the test had been conducted on it. Then, through calculation, the mass of water absorbed is 0.325g. With these data, it can be said that the sample with the least amount of water absorbed after the test is the best which can be clearly seen from the table above, it being the sample from nangka A.

3.3 Ash Content Analysis

The residual non-combustible matter after incineration or burning is referred as ash. In most cases, the ash content of paper will contain inorganic residues from the pulp, inorganic residues from papermaking chemicals, and loading or filling materials deliberately added.

Table 2: Ash content analysis based on percentage

Sample	Net dry weight (g)	Combusted weight (g)	Loss in Weight (g)	Ash content (%)
Commercial paper bag	1.0242	0.0211	1.0031	2.06
Kapas A	0.7850	0.0084	0.7566	3.62
Nipah A	0.6209	0.0281	0.5928	4.53
Nangka A	0.6262	0.0219	0.6043	3.50
Kapas B	0.6182	0.0121	0.6061	1.96
Nangka B	0.6337	0.0258	0.6079	4.07

Table 2 presents the data obtained for net dry weight, combusted weight, loss in weight and ash content of the samples. From **Table 2**, ash content in the commercial paper bag was as low as 2.06%. Therefore, based on the data obtained from the other samples, it can be concluded that kapas B is the best as it had basically the same value of ash content as the standard and even lower which is 1.96%. In this experiment, there are no loading or filling materials added during the production of paper. Therefore, the most likely case is that the ash content refers to inorganic residues from the pulp or inorganic residues from papermaking chemicals and as mentioned, paper with the least ash content is kapas B.

3.4 Moisture Content Analysis

Moisture content can be defined as the amount of water in a material or substance. The moisture content of paper also affects its various mechanical, surface, and electrical properties, and contributes to the qualities of printability and runnability in the various printing processes. Uniform moisture content is critical for paper to be free from distortions such as curl, twist and waviness which cause printers and copiers to jam.

Table 3: Moisture content analysis based on a percentage of water loss

Sample	Wet weight of sample (g)	Dry weight of sample (g)	Moisture content (%)
Commercial paper bag	0.5806	0.5424	6.58
Kapas A	0.8524	0.8191	3.91
Nipah A	0.5734	0.5280	7.92
Nangka A	0.6091	0.5521	9.36
Kapas B	0.3724	0.3471	6.79
Nangka B	0.5909	0.5240	11.32

Table 3 presents the data obtained for wet weight, dry weight, and moisture content of the samples. From **Table 3**, moisture content in the commercial paper bag was 6.58%. Through the samples tested, the one closest to the standard is kapas B which is 6.79%. Kapas B is proven to be the most suitable for printing works for the same reason mentioned.

4. Conclusion

To conclude, nangka A is the best in term of absorbency while kapas B is the best in terms of ash content and moisture content. Therefore, it can be said that kapas B is the best overall as it conquers the two aforementioned aspects of analysis while also being the third best in term of absorbency which is not that far from the standard.

For the paper production, the best amount of pulp required might be between 20g and 40g. This can be seem most probable as the papers in first phase production are thick and hard but do not have any holes in them. On the other hand, the ones from the second phase production are thinner and softer but have holes in them. Therefore, the suggestion on the best amount of pulp to be used is 25-30g. The flaws that papers in both first and second phase production possess made it impossible for the kraft paper bag production. Hence, with the suggested amount of pulp, it is speculated that the ideal paper bag can be produced as initially proposed.

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