Potential of *Musa Sapientum* and *Imperata Cylindrica* as an Alternative Raw Material for Packaging Paper

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Abstract

Until now, most of the pulp and paper production in the world is made from wood plant fibers. Due to the increasing demand in paper industries and shortage of wood origin material in paper-based industries, non-wood fibers have been explored to find the best alternative raw material to produce paper. One of the non-wood fibers that have potential of being raw material in paper-based industries is banana (*Musa Sapientum)* due to its similar characteristic with wood fiber. Banana fiber has wide range of uses in handicraft industries to make mat, rope and many more. Other than banana fiber, cogon grass (*Imperata Cylindrica*) is also an agricultural waste which is capable to be raw material in paper-based industries and hence preventing the environmental problems. Therefore, this study aim to determine the suitability of banana pseudo-stem fiber and cogon grass fiber for packaging paper productions. The method used to make pulp in this study is chemcical pulping using alkali. In conclusion, recent study had proved that banana fiber and cogon grass could be a good potential fiber alternative in paper-based industries in the future. Sample 5 from 80% banana-cogon grass mix fibres showed that it has the highest water absorbency and nearly similar with the reference paper. Sample 5 also showed that it has the highest tensile strength when compared to other samples which can withstand force until 208.044N. The highest elasticity of paper was showed by sample 6 which contain 100% of banana fibre which has the elasticity of 6.603kN/m^2. From thermal analysis of paper that was testing by using Differential Scanning Calorimeter, sample 6 showed that it has the highest melting point and hence it reached the minimum requirement to make a good paper which at 81.73 °C. From functional group analysis of paper that was testing by using Fourier Transform Infra-Red (FTIR), all of the sample showed that they have nearly similar peak and functional group of packaging paper.

Keywords: Banana trunk fiber; cogon grass; packaging paper; alternative raw material.

1. Introduction

Paper is one of the greatest inventions that play a huge role in our daily live, its uses are not only limited for writing but also packaging, printing and wrapping material. In the past, the major resources for making pulp and paper were from non-woody plant such as cereal straw, reeds and esparto grass (Waham & Rahman, 2015). Papermaking from non woody is thought to have originated in China and Ts'ai Lun was the first person that came up with the idea to make paper using rags and mulberry plant as the raw material (Carr, 2017). However, the insufficient supply of the traditional raw material such as cotton and rags in the 19th century became a good reason to replace the material by using wood to make paper (Aripin, 2014).

Nowadays, most of the pulp and paper production in the world is made from wood plant fibres. However, the environmental concern is now increasing over the year to meet the demand of paper-based product (Kirwan, 2012). As a result, huge area of rainforests was destroyed every year to meet the supply and demands of wood fibres (Taylor & County, 2012). Eventhough there are many reasons for deforestation but most of them were related to fulfil the demands for paper-based products (Covington, 2013). Hence, alternative raw materials are been introduced to replace the used of wood as raw materials.

Banana is an important fruit crop that belongs to the *Musaceae* family. Banana pseudostem is capable of being used as the raw material for pulp and paper making due to the fact that it is fast growing plant and yields high biomass after harvesting (Hussain & Tarar, 2014). The banana plant has a cycle of nine to ten months to bear fruits, after that the remaining parts of the plant is disposed of as an agricultural waste (Preethi, Balakrishna, & Murthy, 2013). All types of banana plants are known to provide fibres abundantly especially the trunk part (pseudo-stem). (Vigneswaran *et al.,* 2015) stated that about 1.5 million tons of dry banana fibres could be produces from the outer sheath of pseudostem. Most of banana plantations do not utilize the banana after harvesting the banana fruit, but just burning them. These can resulting abundant agricultural which may be considerable as a potential to substitute virgin wood fibre to produce pulp and paper (Ramdhonee & Jeetah, 17). The study al o stated that the usage of banana plant in the paper making industries will yield economic and ronmental bonus . The sustainable production of banana paper shall contribute to reduce the stress on depleting natural urces (Goswami, Mahale, & Anita, 2015).

nother raw material used in the study is Cogon grass (*Imperata cylindrical)* which also known as japgrass, grass, speargrass, alang-alang and lalang-lalang (Chris, 2017). Cogon grass is one of the plant that presence abundance and gro ing grass that is widely found in Malaysia (Kassim, et al., 2016). It has short cycle growth compared to wood plants (Aripin, 2014). They are mostly used as fuel to create fire and nothing more (Hashim, 2014). Sometimes this undesirably grass may cause problems to plantation areas (James, Estrada, & Flory, 2015). Due to the abundance, short h cycle and lack of commercial applications of cogon grass, it can be recommended as an alternative fibre in the pulp and paper industries and hence decreasing the demand for deforestation activities.

Non-wood plant fibres that are currently used in the pulp and paper industry are divided into three groups which are natural growing plant, non-wood crops and agricultural residues depends on the availability of the plant fibres (Goswami, ahale, & Anita, 2015). Paper made from agricultural residues will reduce the uses on wood plant from natural forest resources. Table 1 shows the properties of various non-wood fibres in paper industries. Agricultural residues have higher cellulose and hemicellulose but lower in lignin content than others. (Aripin, 2014) stated that the chemical and physical properties of n n-wood fibres are important because it can affect the mechanical properties of the paper as shown in Table 1 (Aripin, 2014).

Table 1: Chemical, physical and mechanical properties of non-wood fibres (Aripin, 2014)

Categories	Raw materials	Chemical properties			Physical properties			Mechanical properties	
		Cellulose, w/w%	Hemicellulose, w/w%	Lignin, w/w%	Fibre length,mm	Fibre diameter,um	Tensile index,mN/g	Tear index, mN.m2/g	Burst index, kPa.m2/g
Agricultural residue	Banana stem	59.18	17.50	18.21	1.55	22.00	47.56	9.10	4.51
	Rice straw	41.20	19.50	21.90	1.41	8.00	26.11	0.31	1.20
	Wheat straw	38.20	36.30	15.30	0.74	23.02	76.70	4.11	3.74
Annual plant	Bamboo	43.00	39.00	31.00	2.70	14.00	n.a	18.10	4.90
	Switch grass	41.20	n.a	23.89	0.76	13.89	75.98	5.60	4.90
Non wood	Palmyra plant fruit	37.01	31.51	18.54	1.07	n.a	13.80	1.12	n.a
	Date palm rachis	45.00	29.80	27.20	0.89	22.30	n.a	4.40	1.32
	Date palm leaves	30.30	n.a	31.20	n.a	n.a	28.30	8.40	1.40

Ther fore the aim for the present study is to investigate the potential of banana stem as alternative fibres for packaging paper. Apart from that, the effect of paper by combining banana stem and cogon grass was studied at different mass ratio at the same condition. Lastly the paper produced will be evaluated in terms of water absorbency, tensile strength, melting point and functional group.

2. Methodology

2.1.0 Materials

The sample of banana (*Musa Sapientum*) trunk waste was collected from Batu Pahat, Johor. Dried cogon grass (*Imperata cylindrica*) was collected at Jalan Purnama, Persiaran Seri Alam. For the paper frame making, A4 size (210 × 297 mm) frame, sieving net, superglue (*cyanoacrylates*) and cellophane tape were act as moulding and deckle.

The outer layer of banana trunk which is pseudo-stem sheath was stripped from each layer into individual sheath. ples were air-dried at ambient temperature for 72 hour (Daud, Hatta, & Mohd, 2014)The fibres were further dried in at temperature 110°C for 24 hour to make sure there were no water particles inside the samples. All fibres (banana cogon grass) were cut in sizes of about 2-5cm with cutter (Ramdhonee & Jeetah, 2017).The fibres were washed and with distilled water to removes any impurities from the materials such as adhered soils and grit. The fibres and lignin raw material were separated by treatments with alkali which partly remove the lignin and other non-cellulose ıents from the fibres. Chemical pre-treatment involved cooking the finely chopped and over-dried banana bits with Sodium Hydroxide, NaOH (Ramdhonee & Jeetah, 2017). The fibres were cook with 1000ml volume of water and concentration of 0.1% Sodium Hydroxide solution in a beaker (*Pyrex, Schott AG 1893*) at 250°C-300°C for about 1-2 hours material becomes very soft. After cooling, the fibres were filtered by using a strainer. The spent cooking liquor ining lignin was allowed to flow through the strainer. After that, the cooked fibres were thoroughly washed with water 30 minutes to remove excess NaOH and were filtered again. The fibres were weight out according to the mass ratio banana-cogon grass as hown in Table 2.

I. Preparation of paper

The washed pulp from banana and cogon grass fibre was blended in presence of water in food blender machine *Panasonic, MX-900M*) until it formed a pulpy consistency (Dwight, 2015). Banana fibres and cogon grass mix mass ratios hown in Table 2.1. Mixed pulp was poured into tub filled with 4 liter of water. The mixed pulp from the tub was lifted and deposited in the frame. The pulp in the frame was spread evenly. Then, the frame was removed from the tub and water allowed to drain. The drained pulp was remove from the frame and was then couching on the cloth. The wet paper was blotted softly with a sponge before removing the cloth. Semi-dry pulp was transfer to a board and was dry in the oven at for 9 hours.

Table 2: Samples of paper according to mass ratio of Banana fibres to cogon grass

Sample ratio Banana fibres to Co on rass	Banana fibres, g	*Cogon grass* ,g
Sample 1	0	100
Sample 2	20	80
Sample 3	40	60
Sample 4	60	40
Sample 5	80	20
Sample 6	100	0

2.2 Characteristics Study of Packaging Paper

.2.0 *Water Absorption Analysis*

Water absorption analysis is the liquid sorption rate of bibulous paper using gravimetric principles. The absorbency ı measured by dropping a known volume of liquid onto the sample surface and time required for the liquid to be absorbed is recorded in seconds (Goswami, Mahale, & Anita, 2015). A dropper was used to drop water on the surface of the samples. The t was run for all of the samples according Table 2 and a reference paper (70 gsm).

2.2.1 *Tensile Strength Analysis*

Tensile strength is the maximum force required to break a paper strip of a given width under prescribed laboratory conditions up to the point of rupture. The tensile test is measured by the change in length while adding weight until the part begins to stretch and finally breaks. The tensile properties in terms of the force at peak and at break were determined using Universal Testing Machine (UTM). UTM is a machine that can calculate the tensile and compressive strength of a material, stretching from both ends by using force or load. UTM type AG-100KNXplus STD is used in this study. Before testing, the thickness of the paper is being measured using Vernier Calliper, having a reading of 1.25 mm equal for all samples and the width of the paper must not exceed the 40 mm mark to get the most accurate result. The length of the paper is depending on the r as long as both end of the paper is longer than the gap between and the paper is been clamp on the movable ead. The TM machine can determine a lot of data such as stress, strain, load and displacement. In this case, the stress over strain and load over displac ment i he most uitable data to obtain the ten ile str ngth of the paper. The paper testing, 0.01 mm/s of velocity displacement is being use during the tensile experiment and maintained for all samples. The following equations (1),(2) and (3) were calculated to calculate the elasticity of paper,

$$\text{tress} = \frac{FORCE}{} \quad (1)$$

$$\text{Strain} \quad \frac{MAX\ DISPLACEMENT}{ORIGINAL\ LENGTH} \quad (2)$$

$$\text{Elasticity} = \frac{STRESS}{STRAIN} \quad (3)$$

2 .2 Thermal Analysis

Differential Scanning Calorimeter, DSC can determine various characteristic of the sample such as glass transition, melting point and crystallization temperature by measuring the heat flow. The difference of melting point determines ariations in material composition in the sample paper. Perkin Elmer-6000 type of DSC is used in this study. The melting point data is essential to determine whether the sample can withstand a lot of heat and from that it can also determine the quality of the sample. The testing was carried out with six different samples according to Table 2. Specifically was cut and w ight to ±5.5 mg before placed in a zero hermatic aluminum pan with the lid sealed. The pan that contains sample paper then plac d inside the DSC machine together with the reference's paper pan. Next, the test chamber is being heated at a temperature from 27°C to 200°C with the rate of 20°C/min. This process is maintained for all samples and the results receive from the D C machine can determine the quality and heat flow of the paper.

2.2.3 Functional Groups Analysis, FTIR

FTIR analysis is used to identify the functional group that present in the sample paper based on the interpretation of an IR spectrum. The peaks in the functional group region will determine the specific kind of bonds. Different functional groups produce bond absorptions at different locations and transmittance on the IR spectrum. Hence it will characterize the chemical composition of the sample papers. The testing is carried out with samples obtained from Table 2. The samples were not subjected to any preparative treatment, and were analysed under ambient conditions, no attempt being made to control the temperature or humidity. Absorbance spectra were acquired using Bruker, VERTEX-700 FTIR spectrometer. The spectra were recorded in the range of 4000 - 650 cm^{-1}.

3. Result and Discussion

3.1 Water Absorption Analysis

Most of the paper has its own absorbency rate and its specific amount of aqueous that it can absorb. The absorbency test was conducted to observe which sample has the greatest quality of paper as shown in Figure 1. The shorter the time taken for the paper to absorb water, the greater the water absorption ability. Figure 1 shows that Sample 6 has the fastest time to absorb water which means that it has the greatest water absorption ability. This is because banana fibre has the highest ability to absorb water due the presence of hydroxyl groups in the chemical structure of cellulose in the fibre. In the other hand, Sample 1 shows the longest time taken to completely absorb a droplet of water as it not consisted any of banana fibre. From this result, we can conclude that sample 1 is the most suitable in making packaging paper as it have the lowest reading of water absorption rate. This is important in determining the packing application because packaging paper such as food packaging should not easily absorb water since it can affect the properties of paper. The water absorption of paper can cause decreasing in mechanical properties such as tensile strength and tear strength (Siracusa, 2012). A conclusion can be made that banana trunk fibre has the greatest moisture absorbency ability while cogon grass fibre have the greatest water resistance ability.

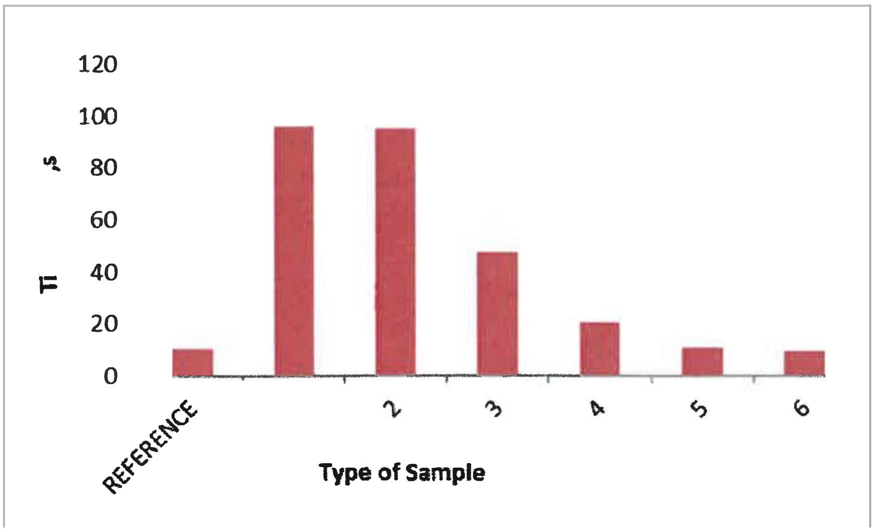

Figure 1: Water Absorption rate for different type of sample paper

3.2 Tensile Strength Analysis

Figure 2 below shows the tensile strength of the sample by using Universal Testing Machine, UTM. The purpose for this test to determine the strength of the paper by measuring the displacement of the paper after force has applied to it. (Caufield, Gunderson, & Madison, 1988) indicates the extent of inter-fiber bonding considered the most important factor contributing to tensile strength properties. The tensile strength is measured by applying maximum load to a sample and determines either the sample can withstand a specified force while being stretched. In the study of paper strength, it can also determine the shear, compressive and tensile strength. Reference paper shows 89.9792N of force that needed to apply for it to break into half. In the other hand, paper from sample 1 shows the lowest quality of tensile strength because it only needs 8.74202N of force to break. Packaging papers require the characteristic of good water and heat resistance and most important can hold heavy and large capacity of substance. Packaging paper is made with an objective to handle huge load and not get torn. Hence, the sample that can handle high force applied when being stretch has a good quality of packaging paper. From this result, it can conclude that the most suitable paper to make packaging paper is the paper that made from sample 5 which giving the best and highest reading of tensile strength that can withstand the largest force compared to other samples and reference paper.

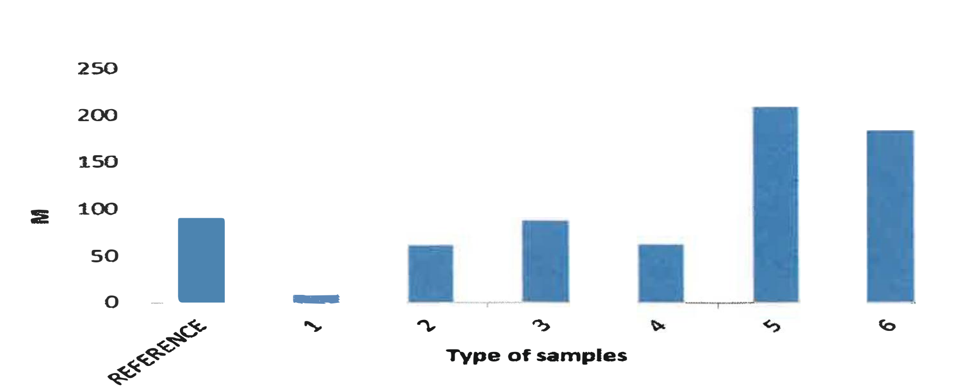

Figure 2: Maximum force of the papers

The elasticity test for paper is important to determine either the sample can easily be torn after being stretched. The the number of elasticity, the more elastic the sample paper will be. Elasticity is an ability of an object to return back to al shape after been stretch or compressed. In conclusion, packaging paper with good elasticity can prevent it from