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Non-Wood for Paper Making: A Review

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Abstract: *Wood have been uses as main source in making paper and lead to the negative effect of environment. Due to the negative effect, this paper introduces about making paper by non-wood plant. In this paper, banana fibre and pineapple fibre were used to replace wood fibre for paper making. Banana and pineapple fibre also mixed with waste paper and sugarcane bagasse in different ratios and give different analysis. The samples were analysis in their absorbency, tensile strength, bursting strength, abrasion and crease recovery. Banana fibre was used with sugarcane bagasse and wastepaper to produce paper in ratios 20:80, 40:60, 60:40 and 80:40. For pineapples was mixed with sugarcane bagasse and wastepaper in 20:80, 40:60, 60:40, 80:20 and 100:0 ratios. The analysis showed that paper mixed by 100% bagasse and banana fibre have nearly similar in absorbency which are 2.17s and 2.155s respectively. Paper from 100% banana and pineapple have least recovery angle which were 32.5˚ and 32.3˚ respectively. Paper that have lowest recovery angle have potentially uses as wrapping paper.*

Keywords: paper making, non-wood, fibre

1. Introduction

Paper uses widely in world in many applications. We can see that paper not only uses in writing and drawing but also as wrapping paper. Wood fibre have been uses as main source to produce paper. Unfortunately, huge areas of rainforest are destroyed every year to supply wood fibre. Due to the trees falling, it can lead to the flood and animals also loss their habitat.

In order to decrease the trees fall, non-wood fibre were uses as main source for paper production to replace wood fibre. Fibre of banana and pineapple were used in this project to replace wood fibre.

2. Literature Review

Banana is one of the most known and useful plant in world. All part of this plant almost can be uses such as fruit, leaves, flower and pseudo stem. Frequently, banana leaf used in food packaging or food processing. We can see banana leaf as food packaging in Malaysia such as Nasi lemak and also kuih such as lepat pisang. Banana fruit can be consumed directly after ripe and also after processed into product such as dried fruit, smoothie and ice cream.

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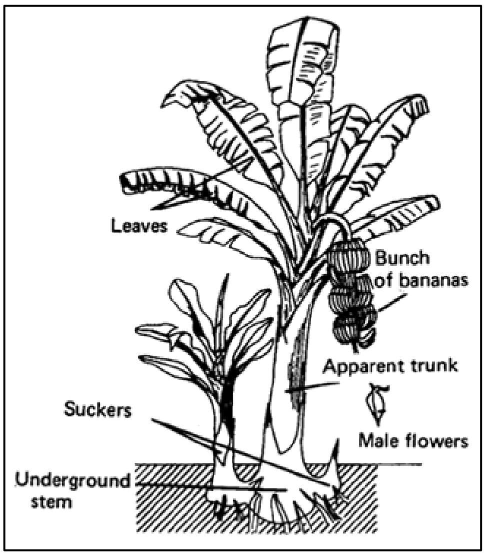

Figure 1: Part of banana plant

The fruit popular as important diet due to its high nutritional content. Besides, flower can be cooked and consumed by diabetics, bronchitis and ulcer patient while young leaf of banana plant can be uses for skin irritation. The banana pseudo stem fiber can be uses in production of paper. Other than that, these fiber also utilizes as fabricate rope, place mats, tea bags and high quality textile. The banana pseudo stem also been considered for use as pulp and raw material, fiber for textile and filler or structural reinforcement in composite (Asmanto Subagyo, 2018). Other name for banana plant is Musa acuminate. These species often consumed by us while Musa textile is known as their fiber.

Pseudo stem function in banana plant as to provide and transport nutrient from soil to fruit. Pseudo stem of banana plant looks like trunk which are consists of soft central core and tightly wrapped up to 25 leaf sheaths. Now, people more realize to focus to pseudo stem in production not only paper but also textile because the rapid increase in consumption of wood fiber based product. These also can lead to illegal logging activity due to decrease permitted wood.

Besides, Ananas comosus fiber also have ability to make paper in order to reduce wood fiber as main source for making paper. Pineapple is famous with the fruit that have unique aroma and sweet taste. This fruit is rich source of mineral and vitamin that offer a number of health benefits. Pineapple fruit also mostly produced food based product after peeling the skin. Pineapple fruit can be seen as jam and juice.

Pineapple leaves fiber have expanded for various purposes including textile, automobile and insulator (Mohd Ali et al., 2020). The high cellulose that content in pineapple leaf fiber are suitable for uses in making furniture as well as building and construction material. In addition, these fiber produces a silky white and strong fiber at an early stage in order to yield maximum vitality and been used to coarse textile and cloth. Pineapple leaf fiber consist of carbon (53%), oxygen (43%) and potassium (4%) are compatible with matrix polymer.

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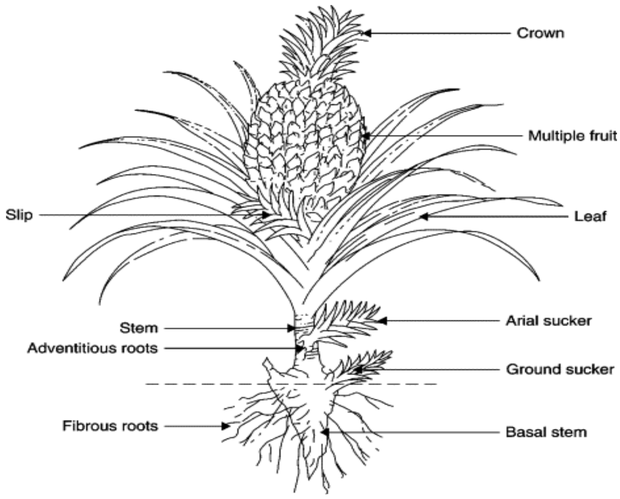

Figure 2: Part of Pineapple

3. Methodology

3.1 Raw material preparation

3.1.1 Banana fiber preparation

Banana fiber were washed and cleaned with water. Extraneous matter such as grit, soil and also excess sap water were removed in this process. The pseudo stem were detached from layered exterior bark and foliage were about 20 cm in width and 60 cm in height (Ramdhonee & Jeetah, 2017). Manually to separated pseudo steam sheaths into individual sheath. Sharp blade was used to tuxy the sheath and extracted fiber were deprived of pith (Ramdhonee & Jeetah, 2017).

3.1.2 Pineapple leaf fiber preparation

Firstly, pineapple leaves were separated from their bundle then washed thoroughly with water to remove dirt and soil. For prevent hand injuries while handling leaves, a knife was used to cut spiky edges of leaves. The leaves were cut into small pieces about 5cm and were allowed to dry in oven at 60˚C for 3 days (Sibaly & Jeetah, 2017).

3.2 Pulping

3.2.1 Banana fiber pulp

For chemical pretreatment, Kraft process was used. In this treatment involved cooking the finely chopped and oven dried banana bits with white liquor which are NaOH and 〖Na〗_2S in 2:5 ratios. The fiber were cooled first before filtered in cloth supported by wire mesh test sieve. The black liquor that containing lignin was allow to flow through the cloth. The brown stock which is pulp with residual lignin were left after filtering process. About 40 minutes, the brown stock was thoroughly washed with water to remove black liquor (sodium lignite) and excess alkali.

The washed pulp was through beating process in electric mixer in presence of water. For separating the beated pulp into accept and reject, screening process was used. Banana and bagasse were mix in 20:80. 40:60, 60:40 and 80:20 ratios in oven dry basic. The movable upper part functioning as deckle was used for paper making. A stop valve was opened and water was allowed to drain off and leave pulp on the mold screen. Couching technique was used which is the pulp was deposited on cloth. By using hand roller, the wet paper was then dewatered to ensure smoothness of paper and facilitate. Next, the moist paper were allowed to dry at room temperature and pressure.

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3.2.2 Pineapple leaves pulp

100 ml of cooking liquor consisting of soda at concentration of 15%w/v as used. The sample was submerge in a beaker that containing 30g of dried pineapple and liquor. The beaker was then placed on hot plate and set to 250 rpm until 300 rpm. Temperature was monitored at 90 +- 2.5˚C using thermometer (Ramdhonee & Jeetah, 2017). For mixing the sample in the beaker, magnetic stirrer was added to beaker and cooking process was done for 90 minutes. For cooling the sample, the mixture was thoroughly washed with water until the effluent became clear and then squeezed them. Unwanted material were removed from pulp such as shives and knot. The squeezed pulp then was dried in oven at 60˚C to obtain dry mass of pulp to be used for paper making.

3.3 Physical and mechanical analysis

3.3.1 Absorbency

The liquid sorption rate of bibulous paper using gravimetric principle (Sibaly & Jeetah, 2017).

Banana fiber	Pineapple leaves fiber
In this study, paper production by banana fiber were measured by dropping a known volume of liquid onto the sample surface. Time required for liquid to be absorbed is recorded in second.	Paper production by pineapple leaves fiber were measured by placing the conditioned sample was on top of an empty and dry beaker so that the center was unsupported.
Absorbency can be measured controlled by using water repellant sizing material such as rosin. Normally, the material is used to delay water absorption rate of paper.	On top of paper, a micropipette was used to transfer 0.01 cm^3 (10µL) of water. A stopwatch was used to recorded the absorbency by started it when the water was dropped on the paper and stopped when water droplet completely disposed through paper. The test repeated 10 times at different place for same type sample.

3.3.2 Tensile straight and tensile index

This test analysis is the highest tensile force needed to rupture a test sample under recommended laboratory condition.

Banana fiber	Pineapple leaves fiber
Maximum force required to break a paper strip of given width under prescribed laboratory condition up to point of rupture (Ramdhonee & Jeetah, 2017). Properties of tensile in terms of force at peak, time to peak and time to failure. Young modulus also were determined using the testometric material testing machine.	8 representative test pieces of 25 +- 1mm wide and 165 +- 5mm long were cut for each type of paper. The sample were tested using universal testometric testing machine to obtain the tensile properties of paper such as elongation at break and force of break. 10mm/min +- 2.5mm/min was set for the rate of elongation (cross head speed).

3.3.3 Bursting strength and burst index

This analysis also termed as Mullen or Pop strength is used to determine the hydrostatic pressure needed to burst a paper sample.

Banana fiber	Pineapple leaves fiber
The test gave indication of amount, proportion and distribution of fiber in the paper which are usually affected by preparation method, beating time and addiction of surface addictive (Ramdhonee & Jeetah, 2017)	8 test specimen were cut using sample cutter for each paper to an equivalent area of 0.01m^2. The test area of specimen was subjected to an increasing pressure by inflating rubber diaphragm and rotation was stopped. The analysis were recorded when rupture appeared or pop sound heard during bursting of specimen (Sibaly & Jeetah, 2017).

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3.3.4 Abrasion resistance analysis.

For this analysis to determine the life span of material as it affect its appearance, strength and functionality.

Banana fiber	Pineapple leaves fiber
Sample of paper production were subjected to intensive rubbing with standard energy paper of grade zero.	8 test specimen were prepared for each type of paper using template of diameter 38 mm and their mass were recorded. By using a rectangular template of size 5”x5”, the abradent was prepared. By used of energy paper of grade zero, the paper sample were subjected to rigorous rubbing. Energy grade paper of grade zero is highly abradent surface and by applying 200g load to obtaion faster result (Sibaly & Jeetah, 2017).

3.3.5 Crease recovery

The sample experiences an accidental fold while being processed. It is an effect which involves stress such as tensile, torsion flex and compression (Sibaly & Jeetah, 2017).

Banana fiber	Pineapple leaves fiber
Creasing quality is an important property of wrapping paper which designates its ability to regain its original position after enduring crease (Ramdhonee & Jeetah, 2017). A zero recovery is designated by 0˚ and full recovery by 180˚.	Rectangular specimen of size 1”x2” were cut using a template. Carefully pleated the specimen by folding into half and gently placed 2kg creasing load which was removed after 1 minutes. After 1 minutes, the crease was allowed to recover.

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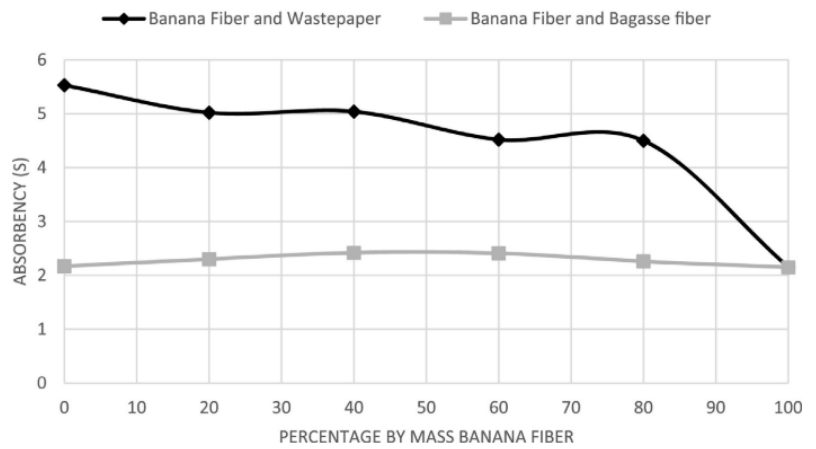
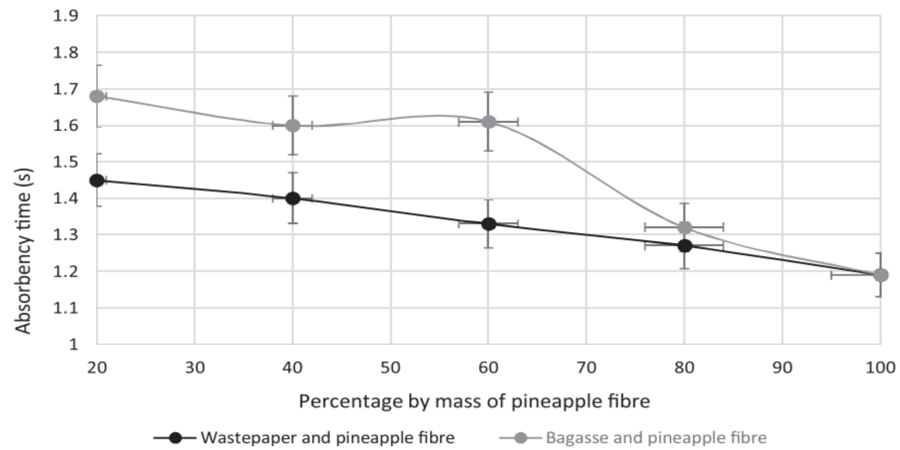
4. Result and discussion

4.1 Absorbency

Water time of absorbency showed that have strong influence on the printability.

<table>
<tr><th>Banana fiber paper</th><th>Pineapple fiber paper</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Absorbency mixture between banana and wastepaper fiber were higher than bagasse mixture.
Paper production from100% bagasse and 100% banana were nearly similar and approximately 2.25 times more absorbent from 100% wastepaper.</td><td>Absorbency for paper by wastepaper and pineapple were lower than composite ratios of bagasse and pineapple with range from 1.27 to 1.45s compared from 1.32 to 1.68s. From the graph also showed that there were slight decreased for bagasse and pineapple (60:40) with 1.60s recorded. These happened maybe because admixture with higher hemicellulose or lignin content and brought to result in higher moisture uptake rate hence lower absorbency time. Besides increasing of pineapple percentage in paper resulting to decrease in absorbency time. These might due to a decrease in cellulose content in mixture which decreased the hydrophilic property of paper produced (Sibaly & Jeetah, 2017).</td></tr>
</table>

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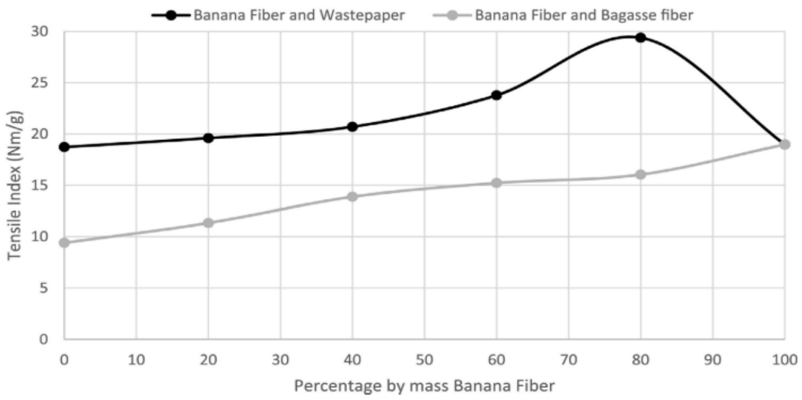
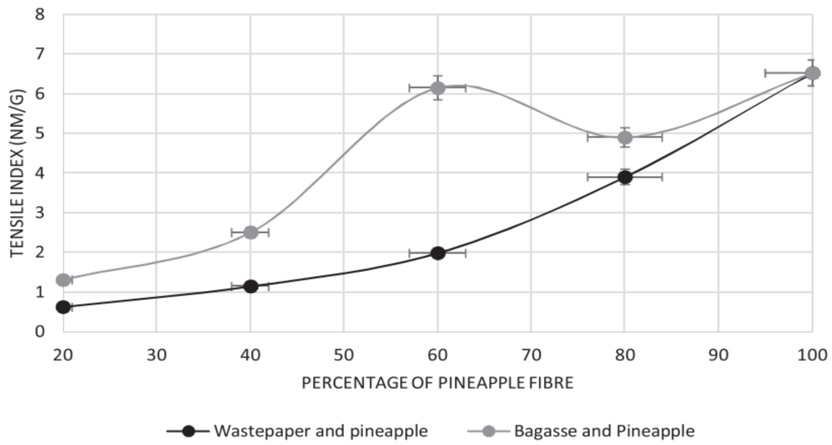
4.2 Tensile strength and tensile index

Banana fiber paper	Pineapple fiber paper
	
Tensile strength is directly proportional to cellulose content (Ramdhonee & Jeetah, 2017). Paper mixture by banana and waste fiber with 80:20 ratios have the maximum tensile (29.4 Nm/g). Tensile index were higher for paper produced with wastepaper than with bagasse fiber. By addition of bagasse for paper making showed the greatest tensile strength for tensile index	For paper made from pineapple was found to increase with increasing percentage of pineapple fiber. Paper made by 100% pineapple was found have maximum tensile index (6.515 Nm/g). Lowest tensile index was found in 80:20 wastepaper to pineapple ratios by 0.618 Nm/g. From the graph shown that paper that have mixture with pineapple and bagasse have higher bonding strength. Due to the highest cellulose content, longer cell length and higher degree of polymerization of cellulose brought to maximum tensile index.

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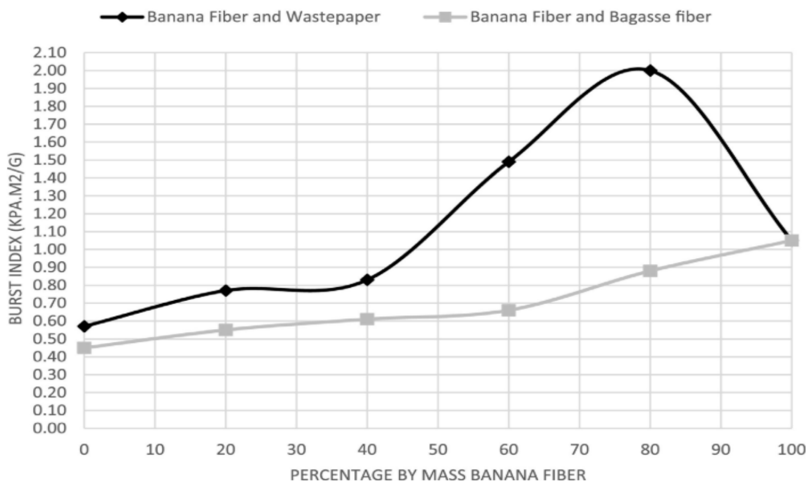
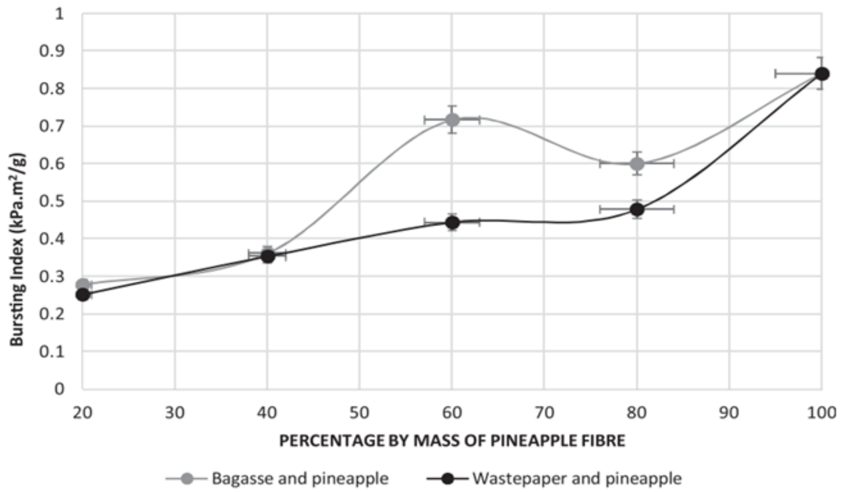
4.3 Bursting strength and burst index

<table>
<tr><th>Banana fiber paper</th><th>Pineapple fiber paper</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Addition about 20% wastepaper in the pulp mix produced the maximum resistant paper of 2.00 kPa m^2/g. When percentage of banana fiber increased from 40% to 80% with wastepaper pulp mix gave improvement in bursting strength. Overall burst advantageously with increasing ratios of banana fiber in pulp (Ramdhonee & Jeetah, 2017).</td><td>Increasing burst index followed by increased in percentage of pineapple fiber. These happened due to the superiority of pineapple leaf fiber mechanical properties related with high content of alpha cellulose and low microfibrillar angle (14˚). Maximum burst index in 0.84 kPa/m^2 by 100% pineapple paper while wastepaper to pineapple in 80:20 ratios is 0. 25 kPa/m^2. Decreasing happened might be due to uneven distribution of pineapple fiber in the paper during preparation method leading to decrease in burst index (Sibaly & Jeetah, 2017).</td></tr>
</table>

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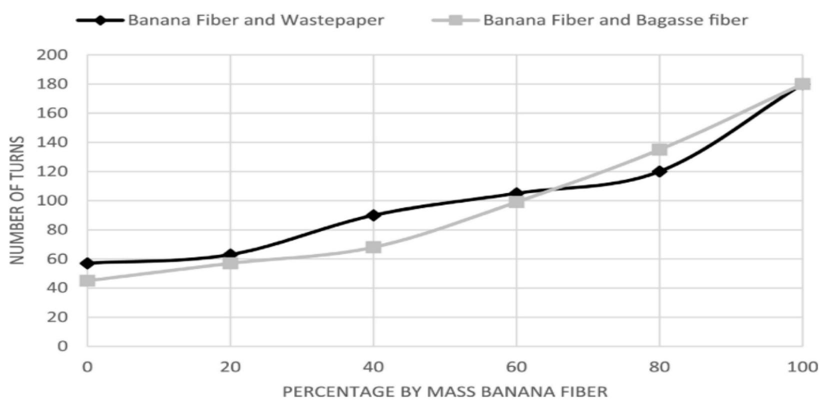
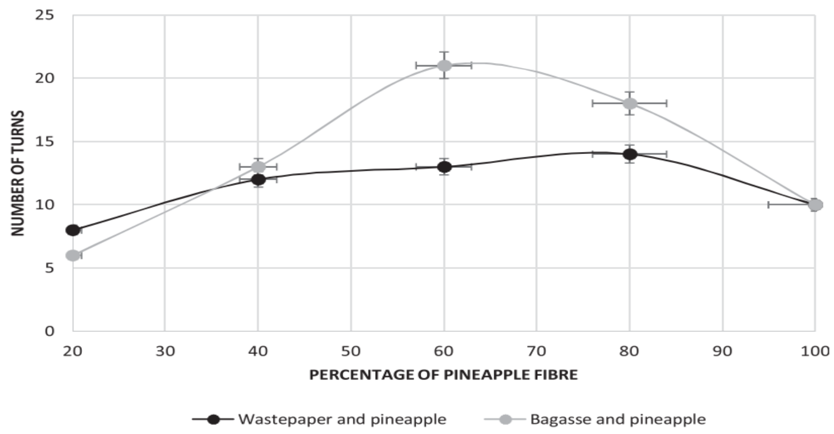
4.4 Abrasion

Banana fiber paper	Pineapple fiber paper
	
Exponential increase in abrasion resistance as the percentage of banana fiber increased in the pulp mix (Ramdhonee & Jeetah, 2017). It indicated that 100% banana paper be the most abrasion resistant. Greatest abrasion resistance with 136 turns and 120 turns by 20% mixture of bagasse and 20% mixture of wastepaper respectively.	Paper mixture by bagasse and pineapple leaves proved to be more resistant to abrasion compared to paper mixture by wastepaper and pineapple. Abrasion resistance showed increasing due to the increasing percentage of pineapple fiber from 9 turns at 20% pineapple fiber to 21 turns at 60% pineapple fiber. These might be due the way the fiber are linked to each other which forms microfibrils provide straight and fundamentally (Sibaly & Jeetah, 2017).

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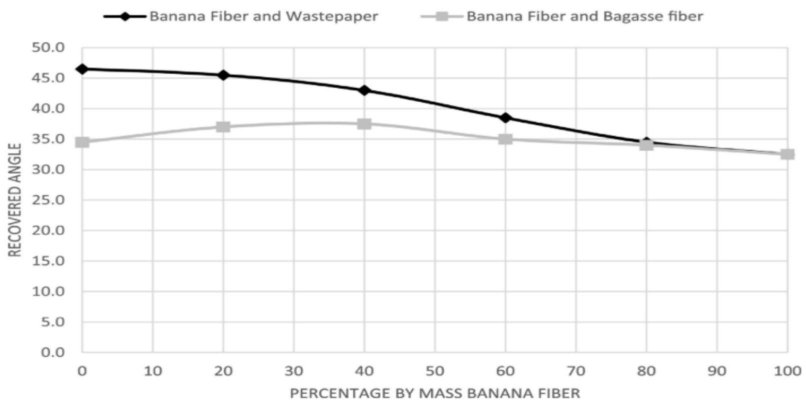
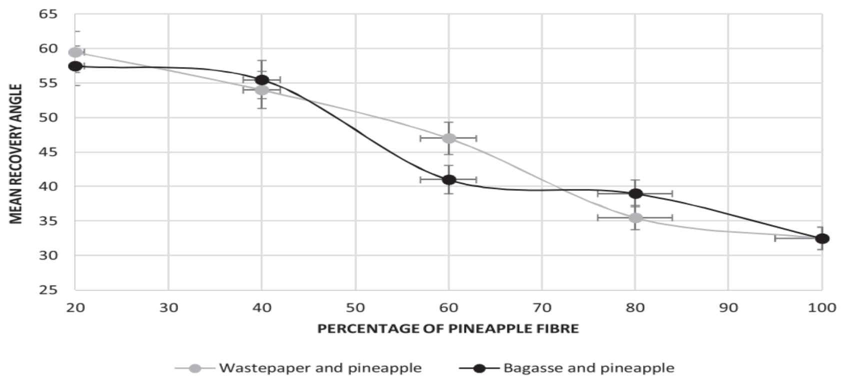
4.5 Crease recovery

Banana fiber paper	Pineapple fiber paper
	
Range angle recorded in 32.5˚ to 46.5˚. A large crease recovery angle is 46.5˚ from paper of 100% wastepaper compared to paper from 100% bagasse fiber (34.5˚). Decreasing in angle recovery due increasing banana percentage in banana and wastepaper pulp mix. The lowest recovered angle was recorded by 100% banana paper (32.5˚) hence banana paper have excellent crease recovery.	Maximum crease recovery angle were 59.8˚ and 57.3˚ by 80:20 wastepaper to pineapple ratios and 80:20 bagasse to pineapple ratios respectively. 32.3˚ was lowest recovery angle found to be 100% pineapple paper showing that have least crease resistant paper.

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5. Conclusion

As the conclusion, paper made from vascular plant such as banana or pineapple have potential to replace trees as main source for making paper. Due to the mechanical and physical analysis, banana and pineapple fiber very suitable as wrapping paper commercial. It is because when paper that have 100% composite of banana and pineapple, they have lowest recovered angle which are 32.3˚ and 32.5˚ respectively. Besides, paper that have admixture composites such as bagasse to pineapple at 80:20 ratios proved that highest absorbency of time and vice versa. Hence different ratios composites in paper gave different properties and can be used according to certain application.

Banana plant also have potential to be used in sector like automobile or construction after modification process (Gupta et al., 2020). In addition, paper admixtures between bagasse and pineapple proved to be more resistant to abrasion. It proved that pineapple fiber can linked strong enough with other fiber and can create good paper like wood paper.

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