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From Waste to Paper

An investigation into the suitability of crop residues as materials for paper

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Abstract

Crop residue is traditionally burnt or taken to landfill by farmers as a convenient method of disposal, however this is associated with negative environmental impacts, contributing to air pollution and climate change. Paper is integral to daily life and is consumed on a large-scale by people across the globe, raising concerns over unsustainable deforestation, thus creating a need to search for alternatives. Many crop residues contain high amounts of fibre and are therefore potential replacements of wood in paper. The aim of this experiment was to determine which crop residue paper, made out of bagasse, corn husk or sugarcane leaf, had the highest tensile strength, highest wet strength, and greatest folding endurance, with these three properties being important factors to consider in papermaking for practical uses. Through a process of retting, cooking and blending, pulp was created from these plant materials and then lifted onto a screen to form pieces of paper. A force sensor and data logger were used to measure the force that was required to break strips of the paper when both dry and wet, and strips were folded to observe whether they were able to withstand tearing. The control for this experiment was paper made from recycled office waste paper, which is made from wood of trees. The reliability, accuracy and validity of this experiment were low as there was difficulty in controlling one vital variable, which was the thickness of each sheet of paper, due to the lack of access to suitable equipment. Therefore, it was unable to be concluded which of three crop residues had the highest tensile strength, highest wet strength and greatest folding endurance. However, it was able to be determined that bagasse had the lowest wet strength and the least folding endurance, whilst sugarcane leaf and corn husk do have the potential to be considered for use in paper production.

Introduction

Crop residue is the waste plant material that remains after harvest, including leaves, stalks, husks and stems. Traditionally, most of this crop residue is burnt or thrown into landfill to rot, in both ways contributing to air pollution and climate change by releasing greenhouse gases such as carbon dioxide and methane, which is 27 times more dangerous to the ozone than carbon dioxide (Using Bagasse for Bioenergy, 2014). Crop residue burning helps growers stay competitive as it is an inexpensive and effective method to remove excess residue (McCarty, 2014), whilst assisting in weed, insect and disease control. However, crop residue burning has significant long-term disadvantages, such as contribution to air pollution, reduction in soil structure, loss of soil nutrients and carbon, impact on soil microbes and fauna, increased soil acidity, and increase in erosion (Agriculture.vic.gov.au, 2015).

Rather than disposing of crop residue in ways that have detrimental impacts on the environment, these waste by-products can instead be recycled and utilised in the production of paper, whilst also conveniently helping people like farmers discard their waste. Human consumption of paper is vast, with world paper production at 400 million tonnes per year (Wwf.panda.org, 2016). Paper is formed by a network of cellulosic fibres (Schmied et al., 2013), which can be obtained from plant-based material. These fibres can be converted into pulp by two processes, chemical pulping or mechanical pulping. Additives can be included as required to enhance certain properties of the paper, however this often comes at the cost of other properties, thus weakening the paper in other aspects.

Strength is an important property of paper, particularly packaging papers, as it is ideal for paper to retain its form and be resistant to tear and other external factors that may cause damage. Tensile strength is a paper's ability to withstand a stretching force, whilst wet strength indicates the strength paper retains after it has been saturated with water (Printwiki.org, 2016). Folding endurance refers to a paper’s ability to withstand repeated bending, folding and creasing (Tappi.org, 2016).

Since handmade paper is typically characterised by a lack of grain direction due to dispersed fibres, it has greater strength when compared to manufactured paper (Handmadepaper-products.com, 2016). Therefore, this experiment incorporated a control to compare the crop residue papers to. The control, which was paper made from recycled wood paper that was office waste, was produced using the same technique as the crop residue papers, therefore allowing the crop residue papers to be appropriately compared to common wood paper.

Sugarcane and maize (corn) waste is copious, being the top two crops with the greatest global production. 1.8 million tonnes of sugarcane and 1 million tonnes of maize were harvested in 2013 (Faostat.fao.org, 2014). Bagasse is the fibrous waste material that remains after sugarcane stalks are squeezed to extract juice for consumption (Using Bagasse for Bioenergy, 2014). Sugarcane leaf is a type of leaf fibre and is waste material from the sugarcane plant. Currently only 50% of the cane biomass available for use is collected (Using Bagasse for Bioenergy, 2014). Corn husk is the leafy outer shell that covers an ear of maize (corn) as it grows on the plant.

Producing more paper from agricultural waste will yield further benefits, as the need to cut down trees in order to produce paper will be diminished, thus helping to alleviate the environmental concerns over unsustainability in regards to deforestation. 42 percent of global wood harvest is used to produce paper, and paper products represent one of the greatest components of landfills, accounting for a third of municipal waste (The World Counts, 2014). Currently, alternative fibres only account for less than 10 percent of fibre in paper and packaging (GreenBiz, 2011). Research and development into the use of crop residue, a promising alternative, is continually being extended today, with a growing number tree-free paper products emerging on the market.

Aim

To determine which type of crop residue (bagasse, corn husk or sugarcane leaf) produces paper with:

a) The highest tensile strength
b) The highest wet strength
c) The greatest folding endurance.

Hypothesis

The sugarcane leaf paper will have the highest tensile strength, highest wet strength, and the greatest folding endurance. The bagasse paper will have the lowest tensile strength, lowest wet strength, and the least folding endurance.

Risk Assessment

Activity description: This activity involves creating pulp by retting, cooking and blending bagasse, corn husk, and sugarcane leaf, and blending recycled wood paper in order to produce paper. This paper is to be tested for tensile strength, wet strength and folding endurance.

Step 1: Identify the hazard	**Step 2: Strategies to minimise the hazard**	**Step 3: Assessment of risk**	**Step 4: What if something goes wrong?**	**Step 5: Packing up**
Glassware can break and cause cuts	Place glassware away from edges of benches and keep outside dry to minimise slipperiness	1 + 2 = 3 = MODERATE	In case of breakage consult an adult. Empty glassware, brush up and place in 'broken glass' bin. Wipe up any spills. If cuts occur, seek first aid.	Clean, dry and pack away carefully
Blades of scissors can cause cuts and injuries	Face scissors away from the body when in use and do not run with scissors. Ensure gloves are worn when cutting plant material	1 + 1 = 2 = LOW	Close blades of scissors and seek first aid.	Close blades of scissors after use and pack away.

Sharp point of drawing pins can cause cuts and injuries	Keep points of pins away from the skin and ensure the box is away from edges of bench to prevent pins from dropping on the floor.	1 + 2 = 3 = MODERATE	Seek first aid.	Ensure all unused pins are placed back in packaging, which should be sealed shut.
Sharp edges of sugarcane leaves may cause cuts and injuries	Ensure gloves and safety glasses are worn when handling sugarcane leaves and keep them away from the face.	1 + 1 = 2 = LOW	Seek first aid.	Ensure all unused sugarcane leaves are placed back into its bag
Gas stove can leak gas, which is toxic when inhaled	If the flame does not ignite, turn the control knob so that the stove is turned off and use other stove top instead	3 + 1 = 4 = MODERATE	If gas can be smelled, turn off control knob immediately. If gas smell persists, seek electrician immediately.	Ensure control knob is switched off immediately after use.
Hot flame can cause burns	Keep skin and face away from flame at all times. Wear gloves	2 + 1 = 3 = MODERATE	Turn off flame immediately. Run burned area under cold water. Consult an adult and seek first aid	Turn off flame immediately after use
Flame may catch other objects on fire	Keep pot placed on open flame at all times. Keep all other objects away from stove top	2 + 1 = 3 = MODERATE	Turn off flame immediately. Place ignited object in kitchen sink and run under cold water immediately, or use a fire extinguisher. Consult an adult.	Turn off flame immediately after use
Hot water can cause burns.	Ensure that pots are stable when sitting on stove tops at all times. Keep hands away from water at all times and wear gloves	2 + 1 = 3 = MODERATE	Run burned area under cold water. Consult an adult and seek first aid	Carefully pour hot water into sink and run pot under cold water immediately after use
Hot pot can cause burns	Ensure that the pot is stable when sitting on the stove top at all times. Keep hands away from	2 + 1 = 3 = MODERATE	Run burned area under cold water. Consult an adult and seek first aid	Run pot under cold water immediately after use. Clean, dry and pack away

	metal areas of pot at all times and wear gloves. Only carry pot by the handles.			
Prolonged exposure to sodium carbonate (washing soda) may cause irritation to skin and eyes. Ingestion can be hazardous and inhalation may cause lung irritation	Keep sodium carbonate away from face at all times. Ensure lab coat, gloves and safety glasses are worn when handling sodium carbonate	2 + 1 = 3 = MODERATE	Eye Contact: Immediately flush eyes with plenty of water for at least 15 minutes. Consult adult and seek medical attention. Skin Contact: Immediately flush skin with plenty of water. Remove contaminated clothing and shoes. Wash clothing before reuse. Thoroughly clean shoes before reuse. Consult adult and seek medical attention. Seek fresh air if inhaled. Consult adult and seek medical attention if inhaled or ingested	Ensure packet of sodium carbonate is closed tightly immediately after use. Clean up any spills and wipe bench with paper towel and gloves.
Contents of blender may come out of the blender whilst being processed and cause injuries	Ensure the lid is placed firmly on the blender while in use. Ensure safety glasses and lab coat are worn.	1 + 1 = 2 = LOW	Turn off blender immediately and clean up spills. If contents come into contact with eyes, flush eyes immediately with plenty of water, consult an adult and seek first aid	Turn off blender immediately. Turn off power switch and unplug from power socket. Clean, dry and pack away carefully after use.
Bulldog clip may cause injuries	Keep fingers and skin away from clamp of bulldog clip at all times	1 + 1 = 2 = LOW	Seek first aid	Ensure bulldog is closed after use
Hook on force sensor may cause injuries	Keep force sensor away from the face at all times and ensure safety glasses are worn	1 + 1 = 2 = LOW	Seek first aid	Ensure force sensor is unplugged from data logger and packed away after use

Mandatory precautions: Covered shoes, safety glasses, hair exceeding shoulder length tied back.

Date: 07/02/16 Student Signature: Sherie Pan

Equipment

- 2 x identical 20x25cm wooden photo frames
- 1 x 1m^2 sheet of fibreglass screen
- 20 x drawing pins
- 1 x 30cm ruler
- 1 x 1.5L Northbrook Spring Water plastic bottle
- 1 x saw
- 1 x craft scissors
- 2 x 25kg rice bags of corn husks
- 2 x 25kg rice bags of sugarcane leaves
- 2 x 25kg rice bags of bagasse
- 2kg of recycled office waste paper
- 1x gardening scissors
- 1 x pair of rubber gloves
- 1 x 9.6L bucket with graduated litre markings
- 2 x identical 14.5x14.5x7cm plastic boxes
- 1 x safety glasses
- 1 x lab coat
- 1 x 5L stainless steel cooking pot
- 1 x gas stove
- 1 x glass thermometer
- 1 x wooden spoon
- 960mL Lectric Washing Soda
- 1 x graduated standard cup
- 1 x phone alarm
- 1 x skimmer
- 1 x 26x56cm net bag
- 1 x table
- 1 x Bio Chef Heavy Duty Professional Blender
- 1 x power socket
- 1 x stopwatch
- Access to tap water
- 1 x 1L graduated measuring cup
- 1 x 15L storage container
- 1 x sponge
- 24 x 21x29cm felt sheets
- 1 x heavy box of books
- 1 x sink
- 1 x roll of Bear 50mmx10m Multipurpose Gaffer Tape
- 1 x 2.8x3.2cm bulldog clip
- 1 x force sensor
- 1 x data logger
- 1 x 22x29x6cm plastic box

Method

Making the Mould and Deckle:

1. The backing material and glass were removed from the two 20x25cm wooden photo frames.
2. Using a ruler, a 24x29cm piece of fibreglass screen was measured and cut out using scissors.
3. The piece of fibreglass screen was placed over the face of one of the frames so that it was taut.
4. The edges of the fibreglass screen were folded over the sides of the frame and tacked into place using five drawing pins on each side of the frame.
5. The frame with the screen attached was the mould, and the other, empty, frame was the deckle. (*Fig. 1*)

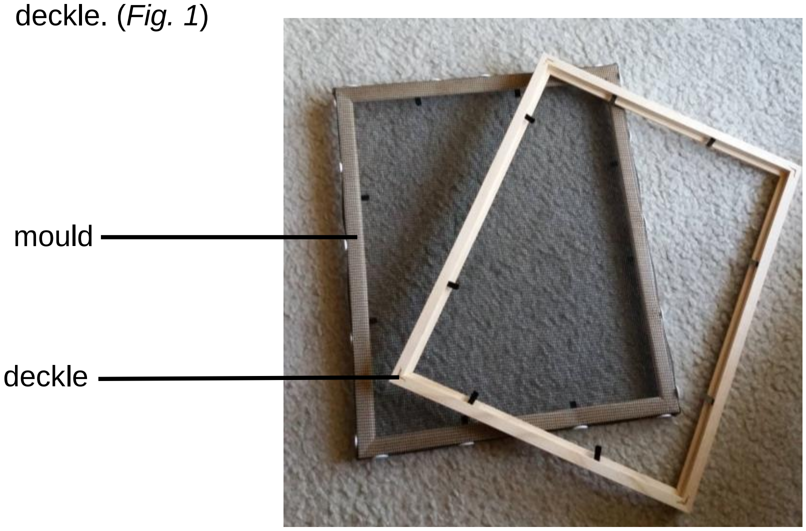


Fig. 1 – mould and deckle

Preparing the Plastic Bottle:

6. The bottom of the plastic bottle was cut off using a saw and scissors, and the bottle cap was discarded.

Preparing the Crop Residue

7. All windows were opened to ensure adequate ventilation.
8. Using the gardening scissors, the bagasse was cut into pieces, where the length of the pieces parallel to the fibres was 6cm, and added to the bucket until it was filled to the 5L mark.
9. The bucket was filled to the top with water and the bagasse was allowed to soak for 30 minutes, with an alarm being set on the timer.
10. The bagasse was removed from the water and placed into the two 14.5x14.5x7cm plastic boxes until they were filled. (*Fig. 2*)
11. The bucket was emptied and any remaining bagasse was left to dry to be reused at a later time.

12. The pot was filled with 4L of water and placed on top of the stove.
13. Using the measuring cylinder, 40mL of washing soda was added carefully to the pot and stirred with the wooden spoon to create an alkaline solution.
14. The stove was turned on high to boil the water. Once the water reached 100°C, measured using the thermometer, the stove was turned on low and the bagasse was added to the pot to cook. A timer was set for one hour.
15. The stove was turned off and the pot was allowed to cool for 10 minutes.
16. Using a skimmer, the bagasse was transferred from the pot to the net bag.
17. The bagasse was rinsed thoroughly under tap water whilst suspended in the net bag.

Fig. 2 – plant material placed into two identical boxes until filled

Making the Pulp:

18. The rinds of the bagasse were removed and discarded so that the pith remained.
19. 600mL of water was added to the blender along with 2.5 cups of bagasse. (*Fig. 3*)
20. The mixture was blended on medium for 60 seconds, timed using a stopwatch.
21. The bottle was held upside down with one hand covering the mouth of the bottle, and the blended pulp was poured into the opening of the bottle.
22. The hand was quickly removed from underneath the bottle and the stopwatch was started. Once all the pulp exited the bottle, the stopwatch was stopped. If the time was not between 0.6-0.8 seconds, the pulp was either: blended for another five seconds on medium if the time was over 0.8 seconds; or ¼ cup of bagasse and 100mL of water were blended in the blender on medium for 20 seconds and then added to the existing pulp if the time was under 0.6 seconds.
23. Step 22 was repeated with the pulp until the consistency satisfied the 0.6-0.8 seconds mark.
24. The pulp was poured into the bucket along with 3L of water.

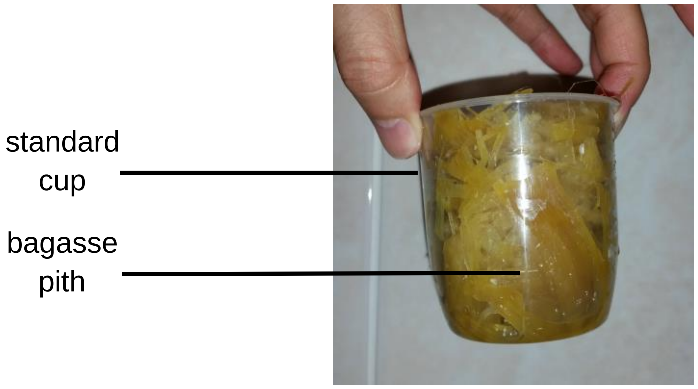


Fig. 3 – one standard cup of bagasse pith

Making the Paper:

27. The mould and deckle were placed into the storage container with the deckle placed on top of the mould, where the smooth side of the deckle was facing down, and the screen-side of the mould was facing up.
28. The pulp in the bucket was poured on top of the mould and deckle so that they became submerged in the pulp.
29. Using the palm, the pulp was spread as evenly as possible across the mould and deckle.
30. The mould and deckle were held horizontally and slowly lifted out of the container so that the pulp formed a sheet across the screen. (*Fig. 4*)
31. The mould and deckle were held above the container to let the excess water drain until it was no longer dripping.
32. The deckle was removed from the mould and replaced with a felt sheet.
33. The mould was flipped upside down, so that the felt sheet was on the bottom, and placed onto the table.
34. A sponge was used to press onto the screen to remove the remaining excess water until no more water came out. (*Fig. 5*)
35. The mould was slowly and carefully removed from the felt sheet so that the paper remained on the felt.
36. Another sheet of felt was placed on top of the paper.
37. The remaining water in the container was poured out.
38. Steps 19-37 were repeated twice more with the rest of the cooked bagasse.
39. The felt sheets and paper were placed under a heavy box of books for one hour.
40. The felt sheets were removed from underneath the box and the top sheet of felt was removed from each piece of paper.
41. The wet sheets of paper were placed outside during the day under sunlight for six hours and in the shade for six hours during the day to allow them to dry.
42. The sheets of paper were removed from the felt sheets and placed under the box of books for 12 hours to flatten them.
43. The sheets of paper were removed from underneath the box.

Fig. 4 – pulp formed a sheet of paper across the screen

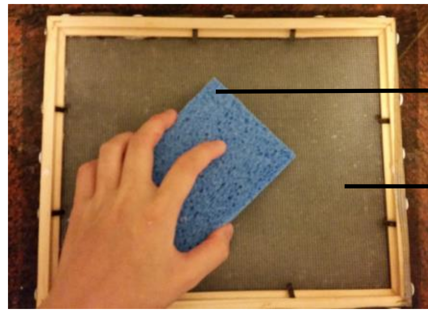


Fig. 5 – sponge used to remove excess water

44. Steps 28-44 were repeated with the corn husks and sugarcane leaves, with alterations to step 18 (the corn husks were left as they were and the midribs of the sugarcane leaves were removed and discarded so that just the softer parts of the leaves could be used) and step 22 (the corn husks were blended for 20 seconds and the sugarcane leaves were blended for 40 seconds to achieve the same consistency of pulp as the bagasse).

Making the Control:

45. Sheets of recycled office waste paper were cut into pieces of 6x5cm and placed into the bucket until it was filled to the 3L mark.
46. 6L of water was added to the bucket and the paper was left for 30 minutes.
47. 600mL of water was added to the blender along with 2.5 cups of wet paper.
48. Steps 20-37 were repeated twice more.
49. Steps 39-43 were repeated with the three sheets of wood paper that were produced.

Cutting the Paper:

50. Using a pencil and a ruler, nine strips measuring 2x20cm were drawn in the centre of each sheet of paper.
51. All strips were cut out using scissors and the nine strips of each piece of paper were separated into three piles of three. (*Fig. 6*)

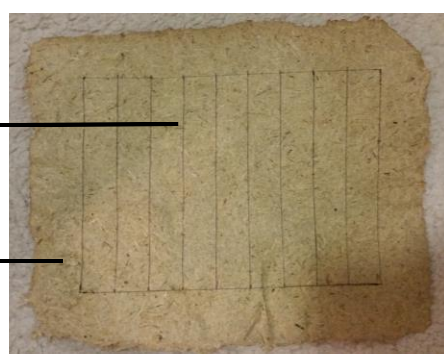


Fig. 6 – nine strips measuring 2x20cm

Testing Tensile Strength:

52. The data logger was placed onto the table and switched on, with the display was set to show the digits.
53. The force sensor was plugged into the data logger and the zero button on the force sensor was pressed to calibrate it.
54. The hook of the force sensor was turned so that it was facing downwards.
55. A 2x5cm piece of gaffer tape was cut out using scissors.
56. A strip of paper was taken from the first pile of the first sheet of bagasse paper and the piece of tape was stuck onto the top of it.
57. The tape and strip of paper was stuck onto the body of the closed bulldog clip.
58. The handles of the bulldog clip were hooked onto the force sensor.
59. The thumb of the left hand was used to hold down the end of the strip of paper whilst the right hand pulled on the force sensor. (*Fig. 7*)
60. The reading on the data logger was observed and recorded at the point that the strip of paper was ripped.
61. The strip of paper and tape were removed from the bulldog clip.
62. Steps 55-61 were repeated with the remaining strips of bagasse paper in the first pile.
63. Steps 55-62 were repeated with the first piles of strips of the other two sheets of bagasse paper.
64. Steps 55-63 were repeated with the corn husk, sugarcane leaf and wood paper.

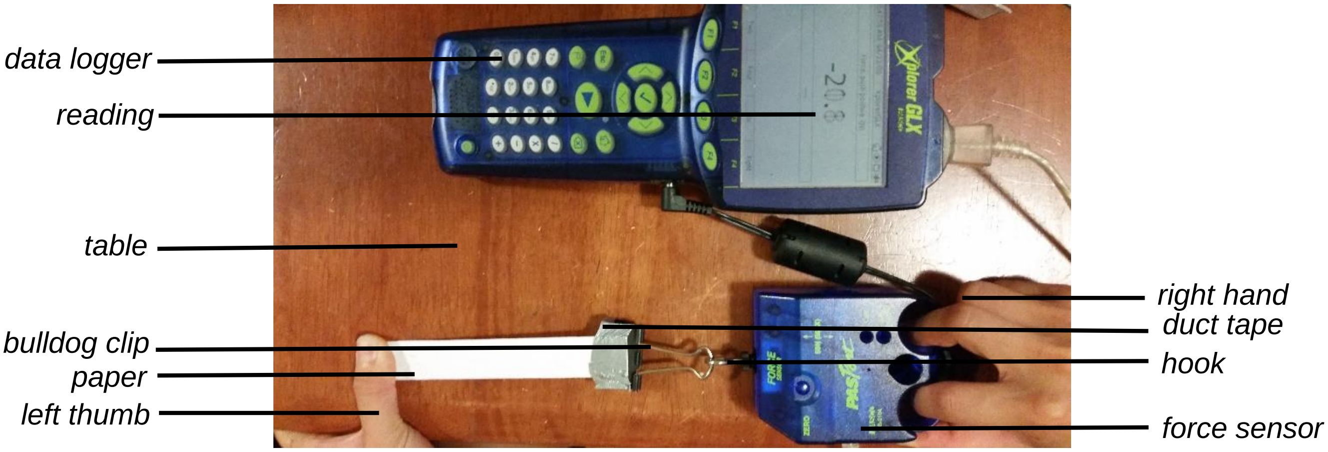


Fig. 7 – Tensile Strength Test Setup

Testing Wet Strength:

65. 1.2L of water was poured into the 22x29x6cm plastic box
66. A strip of paper was taken from the second pile of the first sheet of bagasse paper and placed into the water for two minutes.
67. The strip of paper was removed from the water and clamped into the bulldog clip and placed onto the table.
68. The bottom handle of the bulldog clip was hooked onto the force sensor.
69. Steps 59-60 were repeated. (*Fig. 8*)

70. Steps 66-69 were repeated with the second piles of strips of the other two sheets of bagasse paper.
71. Steps 66-70 were repeated with the corn husk, sugarcane leaf and office waste paper.

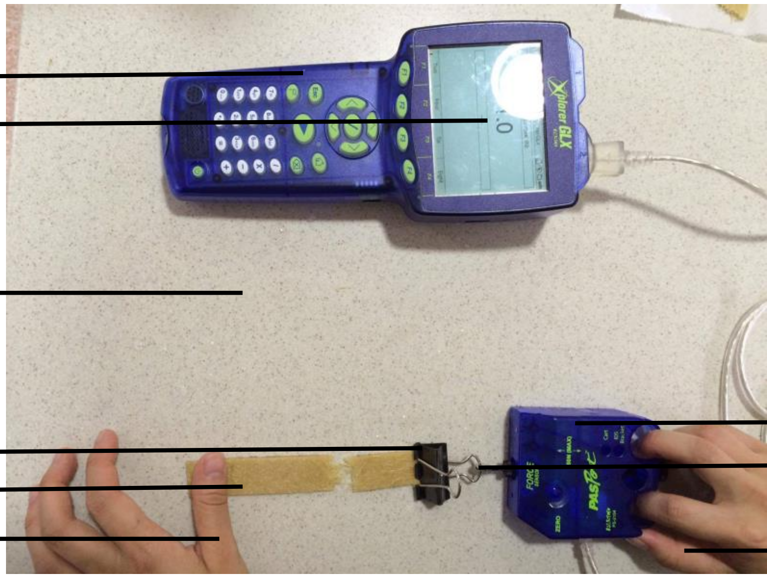


Fig. 8 – Wet Strength Test Setup

Testing Folding Endurance:

72. A strip of paper was taken from the third pile of the first sheet of bagasse paper.
73. The strip of paper was folded in half and it was observed and recorded whether any tears were formed.
74. Step 73 was repeated twice with the same strip of paper and without unfolding the paper.
75. Steps 73-74 were repeated with the third piles of strips of the other two sheets of bagasse paper.
76. Steps 73-75 were repeated with the corn husk, sugarcane leaf and wood paper.

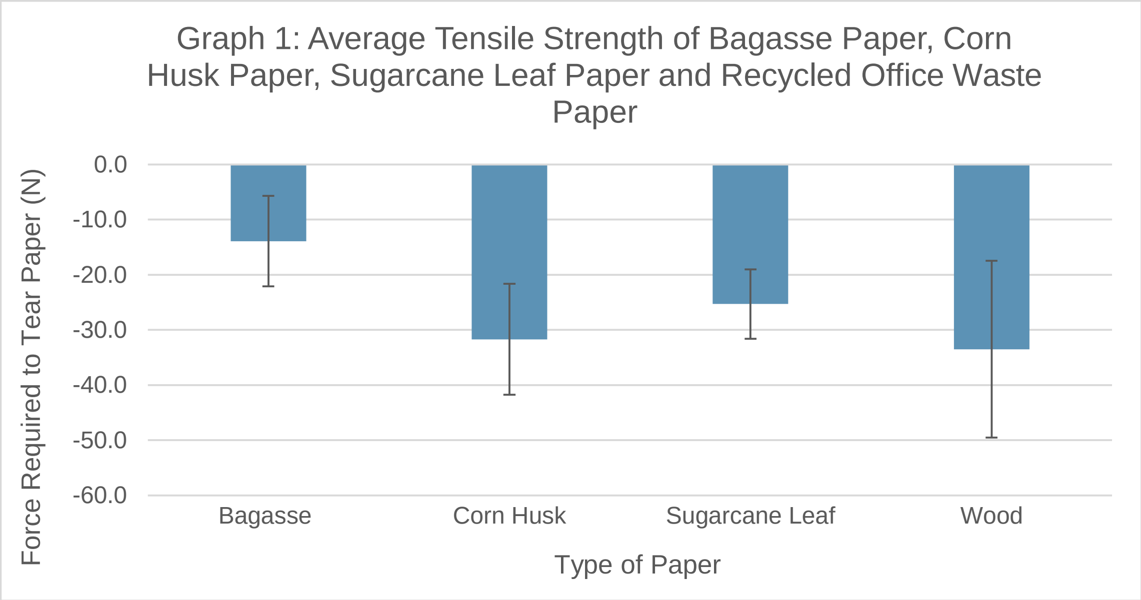
77. Steps 7-76 were repeated seven more times.

Results

Table 1: Average and Standard Deviation of Tensile Strength of Bagasse Paper, Corn Husk Paper, Sugarcane Leaf Paper and Wood Paper

(Raw Data in Table A of Appendix)

Type of Paper	**Tensile Strength (N)**	
	Average (3 sig. fig.)	**Standard Deviation (3 sig. fig)**
Bagasse	-13.9	8.20
Corn Husk	-31.7	10.1
Sugarcane Leaf	-25.3	6.29
Wood	-33.5	16.0

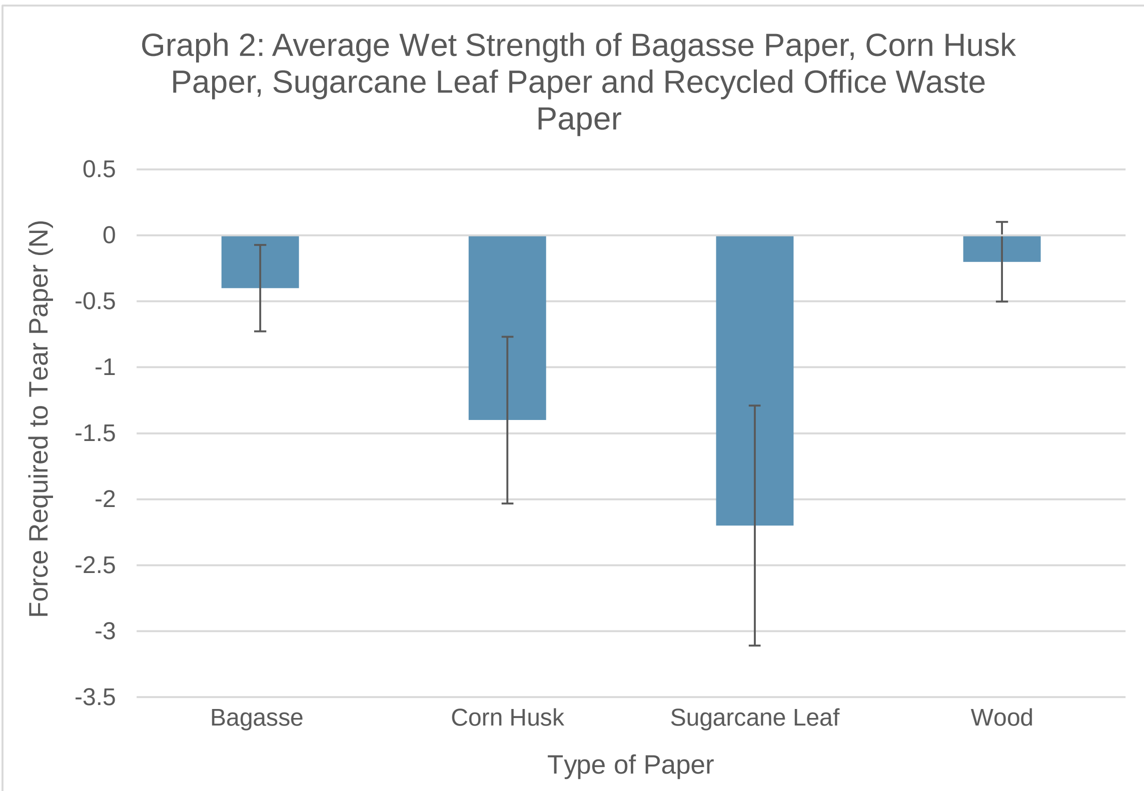


The tensile strength averages and standard deviations were calculated using a Microsoft Excel spreadsheet. The averages were calculated using Excel's AVERAGE function, which calculated the arithmetic mean of the 72 tensile strength results collected for each type of paper. Standard deviation was calculated using the STDEV.P function, which gave a measure how widely the 72 tensile strength values were dispersed from the mean for each type of paper. Graph 1 was created in Excel and the standard deviation values are represented by the error bars.

Table 2: Average and Standard Deviation of Wet Strength of Bagasse Paper, Corn Husk Paper, Sugarcane Leaf Paper and Wood Paper

(Raw Data in Table B of Appendix)

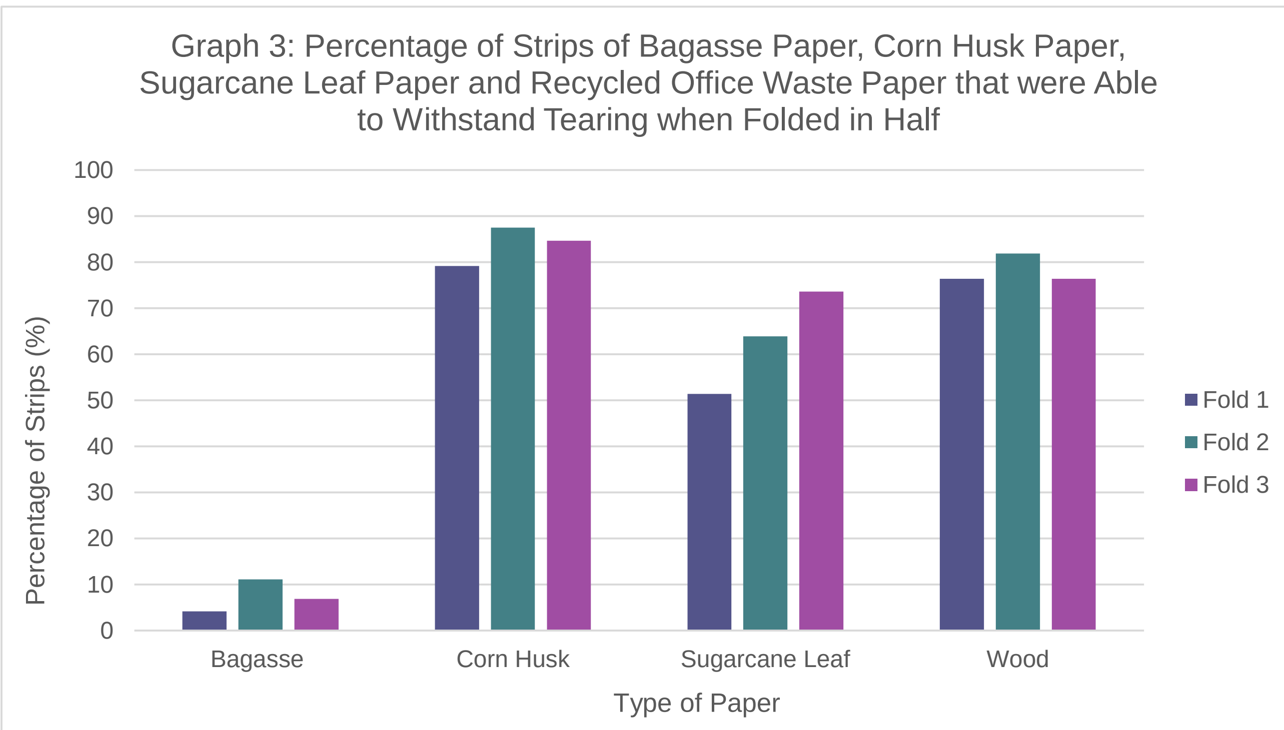
Type of Paper	**Wet Strength (N)**	
	Average (1 sig. fig.)	**Standard Deviation (1 sig. fig.)**
Bagasse	-0.4	0.3
Corn Husk	-1.4	0.6
Sugarcane Leaf	-2.2	0.9
Wood	-0.2	0.3



The calculations for Table 2 were done in the same way as for Table 1. Like Graph 1, standard deviation values are represented by the error bars on Graph 2.

Table 3: Number and Percentage of Strips of Bagasse Paper, Corn Husk Paper, Sugarcane Leaf Paper and Wood Paper that were Able to Withstand Tearing when Folded in Half Three Times

Type of Paper	Fold 1		Fold 2		Fold 3	
	Number of Strips	Percentage of Strips (% 1dp)	Number of Strips	Percentage of Strips (% 1dp)	Number of Strips	Percentage of Strips (% 1dp)
Bagasse	3	4.2	8	11.1	5	6.9
Corn Husk	57	79.2	63	87.5	61	84.7
Sugarcane Leaf	37	51.4	46	63.9	53	73.6
Wood	55	76.4	59	81.9	55	76.4



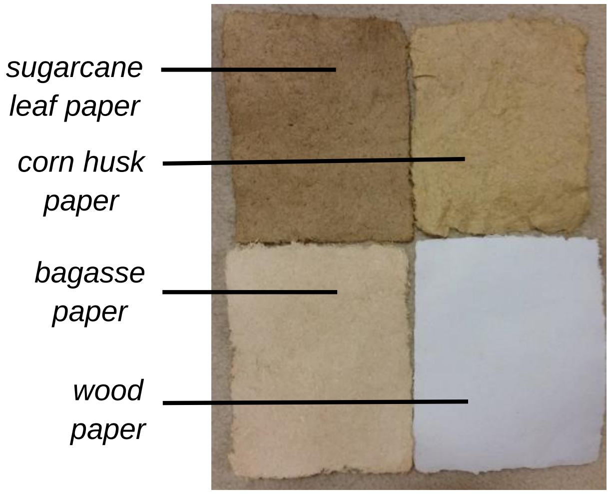


Fig. 9 – all four types of paper

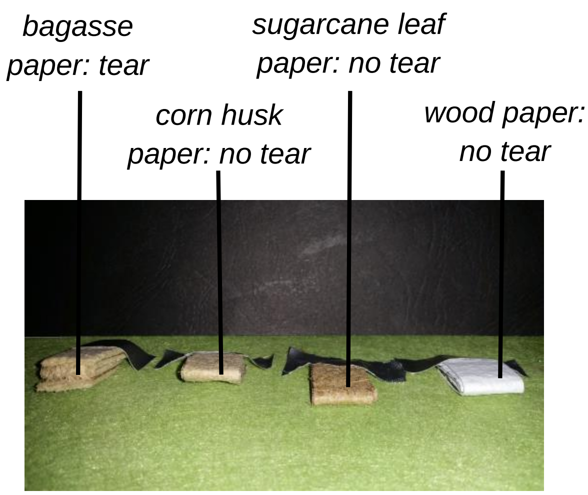


Fig. 10 – samples of all four types of paper on fold 2

Discussion

The results were unable to determine which of the three crop residues was able to produce paper with the highest tensile strength, highest wet strength and greatest folding endurance.

A lower number of Newtons indicated that a greater amount of force was required to pull on the force sensor to tear the pieces of paper, which signified a higher tensile and wet strength. Despite the values for average tensile strength indicating significant differences between the different types of paper as shown in Table 1, where corn husk paper required an average of -31.7N to tear the strips apart, whereas the sugarcane leaf paper just required an average of -25.3N and bagasse only had an average of -13.9, the high standard variation meant that the reliability of the average values was low so they were unable to truly represent the tensile strength of all four types of paper tested. This is demonstrated by the overlap of the error bars on Graph 1, near the value -21N. All four error bars pass through this area on the graph. This means that the tensile strength of the four types of paper could not be differentiated from each other with certainty.

Although it could not be determined which crop residue paper had the highest wet strength, part of the hypothesis was able to be supported by the results, which concluded that bagasse had the lowest wet strength and the least folding endurance, with the average force required to rip the strips of paper being -0.4N, similar to wood paper, which had an average of -0.2N, as indicated in Table 2. The error bars for bagasse do not overlap with sugarcane leaf and corn husk, therefore it can be stated with more certainty that it is has a lower wet strength than the other two crop residue papers. However, the sugarcane leaf and corn husk papers cannot be differentiated as their error bars overlap significantly, as shown in Graph 2. It could also be determined that the sugarcane leaf and corn husk paper had higher wet strengths than the wood paper, which was the control. This is likely due to the fact that wood paper had previously already gone through many chemical processes to become copy paper, and copy paper has less need to be remain strong under wet conditions, so this property was probably neglected in the manufacturing process of the copy paper. This indicates the potential of sugarcane leaf and corn husk papers to be packaging papers, as they are more resistant to tearing when wet.

Again, the lack of reliability meant that the crop residue that produced paper with the greatest folding endurance could not be deduced. The results were very inconsistent, since no type of paper had all strips test positive or negative for a tear on a fold number. As displayed in Table 3, the only value that was close to 0% or 100% was 4.2% for Fold 1 of the bagasse paper, which had a relatively reasonable margin of error. Despite the rest of the results being unreliable, by examining Graph 3, it is still reasonable to infer that bagasse has the least folding endurance of the three crop residues, as there is a significant decrease in the percentage of strips that were able to withstand tearing compared to the rest of the residues.

In this experiment, a large amount of variables were controlled in order to maximise reliability as much as possible. The following table displays the variables which were controlled:

Table 4: Variables that were Controlled in the Method

Preparation method of each type of crop residue	**Pulp-making method of each type of crop residue**	**Papermaking method for each type of crop residue**	**Method of testing tensile strength, wet strength and stretch for each type of paper**
Size of pieces of crop residue	Volume of fibres and water in blender	Same mould and deckle used to make each piece of paper	Size of each paper strip
Cooking time	Consistency of pulp produced	Size of each piece of paper made	Use of same equipment: same data logger and force sensor
Amount of water and sodium carbonate used	Volume of water and pulp placed in storage container for the production of each sheet of paper	Drying method of papers	Amount of time strips of paper were left in water for
Same temperature for stove	Same equipment (e.g. blender)	Amount of time each sheet of paper was left to dry	Size of folds when folding endurance was tested

The sources of the sugarcane leaves and bagasse were the same, meaning that they were very likely to have been produced under the same conditions. The wood paper used throughout was also of the same brand and type. However, the source for the corn husk was unable to be controlled, as the corn husk was collected from two different areas of Paddy's Markets. As a consequence, the conditions that the corn husks were grown in would have been inconsistent with each other and the corn species could even be a different type, meaning that there would have been variations in the corn husks, such as the density and strength of the fibres. It would have been better to only use one type of corn husk than the two different types to improve reliability and validity.

Despite much effort in controlling many variables as displayed above in Table 4, the reliability of this experiment was still of a low level, indicated by the inconsistency of the results. The wide spread of data collected can be seen through the high standard deviations for tensile strength and wet strength. For example, the standard deviations for tensile strength of results for bagasse, corn husk, sugarcane leaf and wood paper were 8.2, 10.1, 6.3 and 16.0 respectively, as displayed in Table 1. This lack of reproducibility was mainly due to the fact that there was a lot of difficulty in controlling an important variable, which was the thickness of the paper produced.

The lack of uniformity of the paper produced meant that depending on the location of thinner and weaker areas on the strips of paper, different forces would have been required to rip the strips of paper. One reason for the difficulty in controlling the thickness of the paper was the access to resources and equipment. In the paper industry, hydraulic presses are generally used to remove the water from paper, and these machines apply pressure evenly across the whole sheet of paper, allowing the fibres to be evenly distributed. However in this experiment, it was extremely difficult to maintain the thickness of the each sheet of paper using the mould and deckle. The fibreglass screen tended to be saggy in some spots and tighter in others as it was extremely difficult to tack the screen onto the frame in a way that the whole screen would be completely flat. Throughout the process of producing the paper, the fibreglass seemed to become looser after frequent use. Additionally, with Step 34 of the method, which is shown in *Fig. 5*, when the sponge was used to press onto the screen to remove the excess water, the force placed on the paper underneath the sponge often meant that the paper fibres underneath would spread out a little, making the paper thinner underneath the sponge and then thicker around the sponge, leading to inconsistencies and less accuracy in the measurements taken with the force sensor. The lack of uniformity in the sheets of paper also meant that some sheets were not flat when they dried and had indents. Another way to assess the accuracy of the equipment used and validity of the method could have been to trial the tensile and wet strength methods (Steps 52-71) using manufactured copy paper, which has a consistent thickness. If the results were inconstant after doing this, this would indicate issues with the equipment used or procedure of the method.

Despite the fact that there was no access to a hydraulic press, a way to help reduce variability in thickness in this experiment could be to use a less flexible type of screen on the mould, as a sturdier screen would prevent it from sagging in different spots. An alternative to using the sponge to remove the excess water could have been to sandwich the wet piece of paper between two felt sheets, place the felt sheets inside a folded towel, and then place three stacks of heavy books on top, rather than one, so that as much water could be squeezed out as possible. Although this would have taken longer for the paper to dry, this alternative would eliminate the use of the sponge and would help apply pressure evenly across the whole sheet of paper. The differing conditions under which different repetitions of paper were dried may also have contributed to inconsistencies, due to the differences in outdoor temperature and humidity on different days. Although it was not possible to complete all eight repetitions of the experiment on one day to allow them all to dry under the same conditions, it may have been a better option to utilise a drying oven instead so that drying conditions can be controlled, as the rate at which the paper dried may have affected its strength and quality of fibre bonding.

In this experiment, instead of measuring tensile strength and wet strength in the conventional way as a force over an area (e.g. N/mm2), only the force was calculated. This was because the thicknesses of the strips of paper varied too much along the strips so it would have been extremely difficult to express it in the conventional way. If it had been possible to keep the uniformity of the sheets of paper consistent, a micrometer could have been used to measure the thicknesses so that the tensile strength and wet strength could be expressed in the conventional way. This would account for variations in thicknesses of different sheets of paper, allowing the final results to be more accurate and valid. In addition, folding endurance is usually tested with a specific device, such as Schopper Double Folder (Smitherspira.com, 2016) that folds paper in double folds in certain ways and the result is expressed as a logarithm. However, there was no access to this device so this method was not used. This meant that the again the folding endurance results were less accurate and valid, as the equipment used in this experiment was not the most preferable or suitable.

Thus, due to the low accuracy and low reliability of the experiment, it also had a low validity. The sample size used was relatively large, with tensile strength, wet strength and folding endurance tests for 72 strips of each type of paper. Increasing the sample size would not have helped in any way to further determine reliability as the equipment and method used in this experiment were unsuitable for any sample size to produce reliable results.

This experiment was able to determine that bagasse would not be suitable as an alternative for wood in paper due to its low wet strength and folding endurance. It is unclear whether or not sugarcane leaf and corn husk have the potential to materials used in paper production. However, despite not being able to deduce decisively whether or not corn husk and sugarcane leaf have high tensile strengths and folding endurance, it can be observed from Graph 1 and Graph 3 that the results collected were relatively similar to the wood paper. Dry strength additives, such as polymers, are greatly used in printing paper (Pulp paper mill, 2012), so since the wood paper was created from recycled office waste paper, the pulp would have already undergone chemical processing to reinforce its strength, whereas the crop residue had not. This is likely to mean that corn husk and sugarcane leaf are naturally able to produce paper that is of a suitable tensile strength, hence making it an option to consider in the production of paper. These two crop residues could be particularly useful in creating packaging papers or cardboards, since they had higher wet strengths than the wood paper and the colour of packaging papers and cardboards generally does not have to be white like copy paper, meaning that they would not have to be bleached.

If the suggestions to improve the method of the experiment explained above could be applied and more suitable equipment could be utilised, further investigations could be to look into the suitability of similar crop residues to corn husk and sugarcane leaf, such as rice husk, barley husk, coconut husk, banana leaves and wheat leaves, as possible alternatives to wood in paper. Another experiment could also investigate the effectiveness of bleaching agents, such as chlorine or hydrogen peroxide, on crop residue papers to investigate the possibility and capabilities of using these waste materials in copy papers, which require a high degree of paper whiteness. Paper, particularly copy paper, is used frequently on a daily basis by all people, so it would be highly advantageous to produce paper using more environmentally-friendly waste materials instead of wood from trees, whilst also being able to deal effectively with the agricultural waste that is already produced. Thus, the ideas presented in this investigation are worthwhile to consider and have the potential to help reduce the human impact on the natural environment by reducing waste and producing paper without having rely on deforestation as much.

Conclusion

It could not be concluded which crop residue produced paper with the highest tensile strength, highest wet strength and greatest folding endurance, although it could be determined that bagasse produced paper with the lowest wet strength and least folding endurance out of the three crop residues.

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Evaluation of Sources

The websites used as references were all valid, relevant and useful to assist in my research for this experiment. They were mostly reliable and relatively current, with many having been updated in 2016, and the least recent being in 2011. A few of them were known to be reputable sites, such as gov. and org. sites. The other sites were used as the information that contained were often relatively specific and detailed so were not commonly found on the gov. and org. sites. Most sources were very factual and objective, however, sites such as The World Counts and WWF were more biased and were likely to have cherry-picked the facts that they included on their pages. A large majority of the information found in these websites could also be substantiated in other sources, so the accuracy of the information was high. Therefore, the sources chosen to be used have been of a relatively high quality.

Appendix

Key:

- B: bagasse paper
- C: corn husk paper
- S: sugarcane leaf paper
- W: wood paper

- 1: paper made during first repetition of method
- 2: paper made during second repetition of method
- 3: paper made during third repetition of method

Etc. up to 8

- X: 1st piece of paper made for the specified material and repetition of the method
- Y: 2nd piece of paper made for the specified material and repetition of the method
- Z: 3rd piece of paper made for the specified material and repetition of the method

Table A: Tensile Strength of all Tested Strips of Bagasse Paper, Corn Husk Paper, Sugarcane Leaf Paper and Wood Paper

Paper	Tensile Strength (N)		
	Trial 1	**Trial 2**	**Trial 3**
B1X	-6.2	-3.2	-2.5
B1Y	-10.2	-10.1	-12.5
B1Z	-1.8	-1.9	-1.2
B2X	-22.3	-17.8	-15.1
B2Y	-27.6	-19.3	-17.3
B2Z	-26.7	-27.9	-28.6
B3X	-7.7	-13.6	-17.4
B3Y	-21.7	-24.5	-20.2
B3Z	-22.1	-12.6	-28.2
B4X	-20.0	-23.9	-27.2
B4Y	-21.1	-22.5	-22.2
B4Z	-29.3	-19.2	-19.4
B5X	-3.8	-11.8	-13.1
B5Y	-12.5	-8.2	-4.2
B5Z	-8.9	-16.3	-10.8
B6X	-12.4	-5.4	-3.0
B6Y	-16.0	-26.1	-22.5
B6Z	-3.5	-12.7	-10.7
B7X	-5.7	-3.5	-1.5
B7Y	-16.8	-11.2	-12.5
B7Z	-2.8	-7.6	-4.1
B8X	-2.6	-2.2	-7.8

B8Y	-21.2	-11.2	-19.3
B8Z	-13.2	-13.4	-14.1
C1X	-33.5	-29.3	-29.8
C1Y	-32.0	-36.7	-29.5
C1Z	-27.2	-26.0	-21.0
C2X	-18.4	-23.8	-20.0
C2Y	-21.3	-24.0	-28.0
C2Z	-36.1	-44.4	-38.5
C3X	-42.9	-33.9	-42.9
C3Y	-17.0	-28.9	-28.9
C3Z	-21.5	-16.7	-36.8
C4X	-29.9	-27.7	-31.7
C4Y	-43.0	-46.0	-40.9
C4Z	-39.0	-32.2	-29.0
C5X	-36.1	-36.9	-34.2
C5Y	-46.8	-51.5	-41.2
C5Z	-35.2	-43.8	-38.2
C6X	-29.8	-34.2	-30.0
C6Y	-8.2	-14.0	-11.6
C6Z	-13.0	-41.1	-23.1
C7X	-19.9	-16.4	-13.0
C7Y	-31.2	-38.2	-33.4
C7Z	-37.3	-39.4	-42.4
C8X	-23.3	-13.8	-40.5
C8Y	-39.0	-41.8	-36.5
C8Z	-43.4	-45.1	-47.6

S1X	-24.1	-30.2	-27.3
S1Y	-34.7	-33.2	-28.6
S1Z	-25.3	-16.5	-25.2
S2X	-22.4	-17.8	-14.0
S2Y	-25.3	-27.9	-25.1
S2Z	-29.4	-24.2	-30.0
S3X	-33.7	-23.3	-20.5
S3Y	-19.8	-18.4	-27.0
S3Z	-34.3	-28.9	-28.3
S4X	-30.3	-32.1	-28.1
S4Y	-35.0	-37.0	-34.0
S4Z	-27.1	-23.5	-27.8
S5X	-29.5	-26.9	-21.8
S5Y	-18.4	-22.2	-22.1
S5Z	-28.1	-27.2	-25.1
S6X	-22.7	-18.2	-27.1
S6Y	-21.9	-20.0	-29.5
S6Z	-27.0	-33.5	-31.4
S7X	-24.8	-26.7	-31.4
S7Y	-37.7	-33.5	-33.6
S7Z	-24.4	-22.0	-19.5
S8X	-9.0	-9.4	-17.0
S8Y	-16.2	-21.5	-15.5
S8Z	-20.9	-16.7	-16.6
W1X	-40.9	-34.9	-37.3
W1Y	-37.4	-35.5	-25.3

W1Z	-5.9	-10.8	-4.4
W2X	-41.7	-43.0	-41.1
W2Y	-34.4	-36.2	-41.5
W2Z	-12.7	-28.6	-26.3
W3X	-31.1	-36.5	-35.6
W3Y	-42.0	-41.6	-30.5
W3Z	-5.5	-8.1	-9.3
W4X	-38.1	-44.3	-42.9
W4Y	-6.1	-12.3	-14.0
W4Z	-11.6	-6.4	-14.3
W5X	-46.7	-61.0	-55.1
W5Y	-4.4	-8.3	-23.0
W5Z	-37.2	-23.6	-61.5
W6X	-34.2	-38.5	-48.4
W6Y	-6.3	-10.2	-28.2
W6Z	-44.0	-61.5	-34.2
W7X	-36.4	-45.2	-43.2
W7Y	-49.5	-42.6	-53.4
W7Z	-35.0	-42.0	-50.5
W8X	-44.1	-55.4	-45.7
W8Y	-42.9	-56.5	-39.2
W8Z	-47.4	-57.0	-35.1

Table B: Wet Strength of all Tested Strips of Bagasse Paper, Corn Husk Paper, Sugarcane Leaf Paper and Wood Paper

Paper	Wet Strength (N)		
	Trial 1	Trial 2	Trial 3
B1X	-0.7	-0.2	-0.2
B1Y	-0.1	-0.9	-0.9
B1Z	-0.2	-0.2	-0.1
B2X	-0.9	-0.7	-1.0
B2Y	-0.5	-0.2	-0.2
B2Z	-0.1	-0.5	-0.3
B3X	-0.2	-0.7	-0.8
B3Y	-1.2	-0.2	-0.9
B3Z	-1.5	-0.4	-0.5
B4X	-0.4	-0.2	-1.1
B4Y	-0.8	-0.8	-0.1
B4Z	-0.4	-0.4	-0.8
B5X	-0.3	-0.5	-0.1
B5Y	-0.3	-0.1	-0.2
B5Z	-0.3	-0.3	-0.6
B6X	-0.7	-0.9	-0.4
B6Y	-0.2	-0.8	-0.8
B6Z	-0.5	-0.7	-0.1
B7X	-0.1	-0.1	-0.1
B7Y	-0.1	-0.1	-0.2
B7Z	-0.5	-0.3	-0.2
B8X	-0.1	-0.1	-0.1

B8Y	-0.1	-0.4	-0.1
B8Z	-0.3	-0.1	-0.1
C1X	-1.2	-0.4	-2.3
C1Y	-2.7	-2.0	-2.0
C1Z	-3.6	-3.2	-3.2
C2X	-1.7	-2.2	-1.2
C2Y	-2.8	-1.2	-2.1
C2Z	-0.4	-2.8	-2.9
C3X	-2.8	-1.7	-0.1
C3Y	-2.0	-1.7	-1.5
C3Z	-1.7	-0.3	-0.7
C4X	-0.1	-3.5	-2.4
C4Y	-2.2	-1.2	-3.2
C4Z	-3.2	-2.2	-1.2
C5X	-2.3	-1.9	-3.1
C5Y	-2.5	-3.1	-2.3
C5Z	-2.2	-2.1	-2.4
C6X	-2.2	-1.2	-2.8
C6Y	-0.7	-1.8	-2.6
C6Z	-0.4	-1.2	-1.8
C7X	-3.5	-1.4	-3.7
C7Y	-3.7	-4.1	-1.2
C7Z	-0.6	-2.4	-3.5
C8X	-3.2	-5.6	-1.4
C8Y	-6.5	-4.1	-4.8
C8Z	-2.7	-4.3	-2.9

S1X	-1.6	-1.4	-1.7
S1Y	-2.2	-2.3	-2.4
S1Z	-1.2	-1.9	-1.2
S2X	-2.7	-3.0	-2.9
S2Y	-2.2	-2.2	-1.9
S2Z	-2.0	-2.2	-1.5
S3X	-3.0	-2.3	-3.0
S3Y	-3.1	-3.4	-3.1
S3Z	-2.5	-2.3	-1.9
S4X	-1.4	-1.3	-1.2
S4Y	-1.2	-1.1	-1.3
S4Z	-2.0	-1.2	-1.3
S5X	-4.0	-2.8	-2.6
S5Y	-3.9	-3.2	-2.7
S5Z	-3.6	-3.4	-3.7
S6X	-2.2	-1.9	-1.6
S6Y	-1.7	-2.8	-2.9
S6Z	-3.7	-1.3	-1.5
S7X	-1.5	-1.3	-0.9
S7Y	-4.9	-5.1	-3.5
S7Z	-2.2	-1.9	-2.3
S8X	-1.9	-1.6	-1.5
S8Y	-1.2	-1.8	-1.8
S8Z	-1.6	-1.5	-1.7
W1X	-0.3	-0.1	0.0
W1Y	0.0	-0.1	-0.1

W1Z	-0.1	0.0	-0.4
W2X	-0.1	0.0	-0.2
W2Y	0.0	-0.2	-0.1
W2Z	-0.2	0.0	-0.6
W3X	-0.4	0.0	0.0
W3Y	-0.2	-0.1	-0.8
W3Z	-0.1	-0.1	0.0
W4X	-0.1	0.0	-1.0
W4Y	-0.1	-0.1	-0.3
W4Z	-1.1	-0.1	-0.1
W5X	-0.3	-0.1	-0.1
W5Y	0.0	0.0	-0.1
W5Z	-0.1	-0.1	-0.9
W6X	-0.1	-0.9	-0.1
W6Y	-0.3	-0.8	-1.0
W6Z	-0.9	-0.8	-0.1
W7X	-0.4	-1.0	-0.5
W7Y	-0.1	0.0	-0.1
W7Z	-0.1	-0.1	-0.2
W8X	-0.1	-0.2	-0.1
W8Y	-0.1	-0.1	-0.1
W8Z	0.0	0.0	0.0

Table C: Ability of all Tested Strips of Bagasse Paper, Corn Husk Paper, Sugarcane Leaf Paper and Wood Paper to Withstand Tearing when Folded in Half Three Times

Paper	Ability to Withstand Tearing when Folded in Half								
	Fold 1			Fold 2			Fold 3		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
B1X	No	No	No	No	No	No	No	Yes	No
B1Y	No	No	No	No	No	No	No	No	No
B1Z	No	No	No	No	No	No	No	No	No
B2X	No	No	No	No	No	No	No	Yes	No
B2Y	No	No	No	No	No	No	No	No	No
B2Z	No	No	No	No	No	No	No	No	No
B3X	No	No	No	Yes	No	No	No	No	No
B3Y	No	No	No	Yes	No	No	No	No	No
B3Z	No	No	No	No	No	No	No	No	No
B4X	No	Yes	No	Yes	Yes	No	No	Yes	No
B4Y	No	No	No	No	No	Yes	No	No	No
B4Z	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
B5X	No	No	No	No	No	No	No	No	No
B5Y	No	No	No	No	No	No	No	No	No
B5Z	No	No	No	No	No	No	No	No	No
B6X	No	No	No	No	No	No	No	No	No
B6Y	No	No	No	No	No	No	No	No	No
B6Z	No	No	No	No	No	No	No	No	No
B7X	No	No	No	No	No	No	No	No	No
B7Y	No	No	No	No	No	No	No	No	No

B7Z	No	No	No	No	No	No	No	No	No
B8X	No	No	No	No	No	No	No	No	No
B8Y	No	No	No	No	No	No	No	No	No
B8Z	No	No	No	No	No	No	No	No	No
C1X	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
C1Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C1Z	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
C2X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C2Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C2Z	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C3X	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes
C3Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C3Z	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C4X	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes
C4Y	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes
C4Z	Yes	No	No	No	Yes	No	No	Yes	No
C5X	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No
C5Y	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C5Z	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C6X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C6Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C6Z	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
C7X	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes
C7Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C7Z	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
C8X	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes

C8Y	Yes	Yes	No	No	No	Yes	No	Yes	Yes
C8Z	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes
S1X	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes
S1Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S1Z	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S2X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S2Y	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes
S2Z	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S3X	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes
S3Y	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
S3Z	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes
S4X	No	No	No	No	Yes	No	No	No	No
S4Y	Yes	No	Yes	No	Yes	No	No	Yes	Yes
S4Z	Yes	No	No	Yes	No	No	No	Yes	No
S5X	No	No	No	Yes	No	No	Yes	No	Yes
S5Y	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
S5Z	No	Yes	No	No	No	No	No	Yes	Yes
S6X	No	Yes	No	Yes	No	Yes	No	Yes	Yes
S6Y	No	No	Yes	Yes	No	No	Yes	No	Yes
S6Z	No	Yes	No	No	No	No	Yes	Yes	No
S7X	No	Yes	No	Yes	Yes	No	Yes	Yes	No
S7Y	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes
S7Z	No	Yes	No	No	Yes	No	Yes	No	Yes
S8X	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S8Y	No	No	No	Yes	Yes	Yes	Yes	No	Yes
S8Z	No	No	No	Yes	Yes	No	No	Yes	Yes

W1X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
W1Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
W1Z	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes
W2X	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
W2Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
W2Z	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
W3X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
W3Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
W3Z	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
W4X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
W4Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
W4Z	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
W5X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
W5Y	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No
W5Z	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
W6X	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes
W6Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
W6Z	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes
W7X	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
W7Y	No	No	No	Yes	No	No	No	Yes	No
W7Z	No	Yes	Yes	No	Yes	Yes	No	No	Yes
W8X	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes
W8Y	No	Yes	No	No	No	Yes	No	No	No
W8Z	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No

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