Investigation into the Mechanical Properties of Banana/Sugar Cane Fibre Paper Blend

*Alebiosu S. O, Adeakin O. A. S, Akindiya I. O, & Oyebode A. A
Department of Polymer & Textile Technology,
Yaba College of Technology,
Yaba, Lagos. Nigeria.

***Abstract*- This research study was carried out to determine the performance and effect of combining long and short fibre in paper making. Bagasse (short fibre) and banana(long fibre) stem were used for the production of paper in this study. This work took the advantage of waste materials from banana and sugar cane stem which were usually discarded by burning or left to rotten. Hand -sheet method was used for the production, the samples from the products were tested for tear strength, tensile strength, and abrasion resistance. The results show that samples composition from 'A' through F were having considerably good tear resistance value range from 0.20 N/mm^2 to 0.13N/mm^2. For tensile strength samples composition from A through F were having good tensile strength value range from 0.42N/mm^2 to 0.38N/mm2 than the rest. F has the best abrasion resistance property.**

Keywords: Banana, Sugar, Paper, Pulp and Bagasse.

INTRODUCTION

Paper consists of a web of pulp fibres derived from wood or other plants from which lignin and other non-cellulose components are separated by pulping with chemical at high temperature. In the final stages of papermaking, aqueous slurry of fibre components and additives are deposited on a wire screen and water is removed by gravity, pressing, suction and evaporation techniques [1].Fibre properties of the raw material affect the quality and use of the paper. For fine papers, both long and short fibres are needed. Long fibres from softwoods (coniferous trees, average fibre length 2-5 mm) or from other fibre species such as flax (Linumusitatissi – mum L.), hemp (Cannabis sativa L.) and kenaf (Hibiscus cannabinus L.,), of fibre length 28 mm, 20mm and 2.7mm, respectively, form a strong matrix in the paper sheet while shorter hardwood fibres (deciduous trees, fibre length 0.6- 1.9 mm) or grass fibres (fibre length 0.7 mm) contribute to the properties of pulp blends, especially opacity, printability and stiffness.

In fine papers, short-fibre pulp contributes to good printability. The principal raw material for papermaking nowadays is wood derived from various tree species.

The main domestic raw materials for fine paper are the hardwood birch (Betula spp.) which accounts for more than 60% of all fibre materials and softwood conifers, usually spruce (Piceaabies L.) and Scots pine (Pinussilvestris L.).

One alternative to using birch for printing papers is to use agricultural residue from herbaceous field crops, as are used in many countries where wood is not available in sufficient quantities.

After the invention of new chemical pulping methods, paper could also be made from agricultural residue. This became the main raw material for paper production in the 20th century.Commercial agricultural residue pulp production has been estimated to be 6.5% of the global pulp production and is expected to increase. The main sources of agricultural residue raw materials for paper production are from monocotyledons, including cereal straw, and bagasse, a fibrous residue from processed sugar cane (Saccharumofficinarum).

The main drawbacks that are considered to limit the use of agricultural residue for paper production are certain difficulties in collection, transportation and storage [2] . Paper industry is presently facing the problem of shortage of raw material and looking for alternative fibrous raw material. Bagasse is a by-product of the stem of sugar cane after crushing and juice extraction. Large quantity of bagasse is produced annually and not much use is made of them except to incinerate. Use of bagasse will lead to conversion of waste to wealth especially for pulp and paper making. Among the variety of unconventional fibrous alternative raw materials, banana stem has maximum potential to be used in paper industry specifically in agricultural residue based mills [3] . Considering the large availability of banana stem waste in the country and shortage of raw materials for producing pulp and paper, study on utilization of banana stem fibre(long fibre) with bagasse for pulp was done to know its effect on the physical properties of paper. More so, banana stem waste is a very good source of cellulose and it cost the producers virtually nothing and it is very effective.

Though many plant fibres have been proposed for papermaking, under test conditions many of them have produced products with desirable properties. A fibrecrop must fit the technical requirements for processing into pulp of acceptable quality. It must also be adaptable to practical agricultural methods and produce adequate Dry Matter (DM) and fibre yield at economically attractive levels [4]. But these desirable properties are not sufficient for their use in the paper industry. Necessary characteristics includes, ample supply of raw material, availability at the pulp mill throughout the year, ability to store without deterioration, geographically concentrated, moderate collection and storage costs, high yield of good quality fibres, low cost conversion to pulp, and sufficient demand for the product at a price that will ensure profitable operation[5] . In 1994, the raw material for the China's paper industry comprised 12.3% wood pulp, 29.1% recovered fibre, 45.4% straw pulp, 4.9% reed pulp, 2.1% cotton pulp, 1.6% bagasse pulp, 0.9% bamboo pulp - and 3.7% other pulps[6] . Fibres that are currently used in the paper industry can be broadly divided into three groups as outlined below based on their availability. However, of interest is the agriculture residue.

(i) Agricultural residues e.g. Sugarcane bagasse ,Corn stalks , Rice straw and Wheat straw
(ii) Natural growing plants e.g. Bamboo, Esparto, Reeds and Papyrus e.t.c.
(iii) Crops grown primarily for their fibres e.g. BastFibre, Jute, Ramie and Kenafe.t.c

The major obstacle in pulping bagasse is the high pith content of stalks, which represents about 30% by weight of the stalk. The pulp is generally comparable to hardwood pulps[7] .Bagasse has been commonly used in South China as a raw material for paper making[8]. Average fibre length of sugar cane is 1.7mm (0.8-2.8mm), and average fibre width is 0.02mm (0.01-0.034mm). Fibres are thick availed, of varying length and have mostly blunt ends [2].In blends of various proportions, it is used to make printing &writing paper, Bristol board, tissue paper, glassine and greaseproof paper, duplex and triplex paper. Corrugating medium, linerboard, wrapping and bag papers, multiwall sack and newsprint substitute.

The chemical compositions of agricultural residue materials have tremendous variationsin chemical and physical properties compared to wood fibers [9] . They vary,depending on the agricultural residue species and the local conditions, such as soil and climate [10].The agricultural residue materials generally have higher silicon, nutrient and hemi-cellulose contents than wood [4].

MATERIALS AND METHODOLOGY

Banana Stem, Bagasse, Hydrogen Peroxide, Sodium hydroxide, Calcium Carbonate, Starch, Wire Screen, Rolling Pin, Heating Mantle, Measuring Cylinders, Weighing balance, Beakers, Universal Testing Machine, Abrasion machine.

METHODOLOGY

Paper Making Method

Collection of raw material
↓
Sorting and cleaning of the material
↓
Chopping of the raw material
↓
Crushing of the raw material
↓
Pulping of the raw material
↓
Grinding of the Pulp Obtained
↓
Sheet formation
↓
Couching of the formed sheet of paper
↓
Drying of the Paper
↓
Pressing of the sheet
↓
Trimming of the paper

OUTLINE PROCESS OF PRODUCTION OF PAPER MATERIALS

Studies were conducted on banana stem collected from University of Lagos garden in Yaba Local Government area and sugar cane was also obtain from the same garden and the juice was extracted by crushing in a mortal likewise the banana stem was dewatered by crushing. The pulping chemical is sodium hydroxide and Hydrogen peroxide. The apparatus include wire screen, kitchen blender, heating mantle, beaker, measuring cylinders, stiring rod, Rolling pin, Instron Machine, weighing balance.

SORTING OF RAW MATERIAL

The banana stem was sorted such that only the stem is used all the leaves from the branch were removed. The sugar cane too was also sorted to ensure that the sugarcane harvested was matured.

CUTTING OF THE RAW MATERIAL

The raw material (Banana stem and Sugarcane) were cut into chips of small size in order to allow for easy crushing for de-watering of the banana stem and extraction of the sugar cane juice.

CRUSHING OF THE RAW MATERIAL

The bagasse and sugar cane were placed inside a mortal and was crushed separately to remove the water and extract the juice. The mortar and pestle used for crushing is wrapped with polythene bag to prevent the wood from the mortar and pestle from mixing with the pulp.

PULPING OF RAW MATERIAL

The pulping method employed in this study is soda pulping whose main chemical is sodium hydroxide. After the bagasse and banana stem had been crushed and cut into chip of average size 25mm long with a knife the sample of the chips obtained was weighed and kept in an oven for about 2 hours to remove water after which it was removed, and weighed. It was put back in the oven for about 30 min and re-weighed. The process was repeated several times until a constant weight was obtained and the moisture content of the chip was calculated. The chip was cooked in hydrogen peroxide of liquor ratio 7:1 for two hours. During the cooking process, bleaching and pulping took place. The bleached pulp was then rinsed and 2% of total bath NaOHis used to digest the chips for another 1 hour.

At the end of the maceration, the pulp was washed and screened into "accept" and "reject". "The reject" was the one with knots as a result of incomplete reaction of the chips with macerating chemicals. The "accept" pulp was weighed to determine the pulp yield.

BEATING OF THE PULP

The "accept" pulp was beaten using a kitchen blender for 40 minute. At the end of the beating, the refined pulp was mixed with water to a consistency with the calcium carbonate and starch included in a standard form.

SHEET FORMATION, COUCHING OF THE SHEET AND DRYING

There are two methods of sheet formation:

(i) Dipping Method (for fine/thin paper):- The pulp was then diluted with water and put into a masonry through or vat. The lifting mold (Mesh on a wooden frame) was then dipped into the vat, shaken evenly and lifted out with the pulpon it. The consistency of the pulp in the tank was being kept constant.

(ii) Lifting method (All paper and card):- A fixed measure of the pulp was poured evenly onto a mold, which is clamped between two wooden deckles (frame) in a water tank dipped. The mold is then raised, using a lever mechanism, to drain the excess water. The frames are immersed and lifted out vertically, trapping the fibres on the mesh. The thickness is controlled mainly by the concentration of the pulp.

The method of sheet formation employed in this experimental work is the lifting method. The "accepted" pulp that has been mixed to a consistency was poured evenly on the wire mesh and water was drained by gravity or pressing. A woven mat of cellulose fibre was formed on the mold which was sun dried for four hours. After drying the paper formed was carefully removed from the mold and the left in the sun for further drying.

PRESSSING OF THE SHEET FORMED, TRIMMING AND CUTTING

The sheet formed was then pressed using laundry iron by placing the formed sheet in between fabric and ironing was done to make the paper have a luster property. The sheet formed was then cut and trimmed to desired size and shape.

TABLE 1

Sample code	Banana (%)	Sugar cane (%)
A	100	0
B	90	10
C	80	20
D	70	30
E	60	40
F	50	50
G	40	60
H	30	70
I	20	80
J	10	90
K	0	100

Composition of the blend in percentage

COOKING RECIPE

Weight of Fibre	=	150g
Liquor ratio	=	7:1 for H_2O_2
Total bath	=	Weight of Material X Liquor ratio
NaOH	=	2% of total bath
Calcium Carbonate	=	2% of Pulp Weight
Starch	=	3% of Pulp Weight

TESTS

After conditioning, the paper sample was prepared by cutting 7cm by 3cm. A load of 500g was placed on the load cell and the sample paper was gripped to upper and lower grips of the instron machine. Load cell amplifier controls were set to 50, the cross load control panel and recorder control were pressed to start the test until the paper cut. The force required to cut the sheet was read from the machine plot. After conditioning, the sample sheets were left in the laboratory for two days before the test. The samples were also prepared in trousers shape by cutting 100mm by 30mm of the paper formed. An initial tear was made to about half the length by dividing 30mm into two equal parts. The torn side was gripped to the upper and lower grip of the instron machine. The load cell amplifier controls were adjusted to 5 and then the control were pressed to start the test until the tearing was completed. The force required to tear the paper was read from the machine plot.The tests were carried out at the Federal institute of industrial research Oshodi, Lagos (FIIRO) using universal testing machine (M500/25KN). Manufactured by Testometric,England. The abrasion test was also carried out at the Federal institute of industrial research Oshodi. Lagos (FIIRO).

RESULT AND DISCUSSION

In fig. 1 it was shown that blend from A through F were having considerably good tear resistance value range from 0.20 N/mm^2 to 0.13N/mm^2 while from G to K were having a sharp decline strength, with the least tear resistance value of 0.03N/mm^2 at K. Observation from the trend across the plot show that samples with high percentage of banana fibre, has more strength than those dominated by high percentage of sugar cane fibre. Optimum tensile strength was obtained for 100% banana sample.

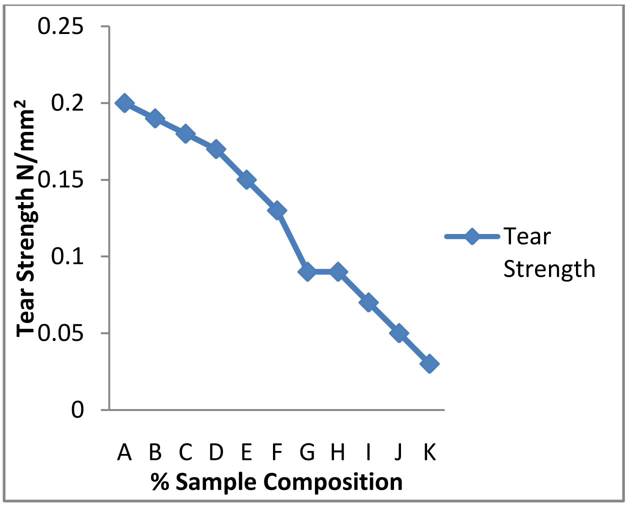

Fig. 1 Effect of blend proportion on tear resistance

In fig. 2 below it was observed that, in term of tensile strength composition with more or equal percentage of banana fibre has better strength than those with high percentage of sugar cane fibre, i.e from K through F where each is having tensile strength value range from 0.42N/mm^2 to 0.38N/mm2,a sharp decline from samples E to sample K of value range from 0.2N/mm^2 to 0.04N/mm^2.Blends below F composition leads to more brittleness of the samples giving a sharp drop in tensile strength as level of sugar cane increases.

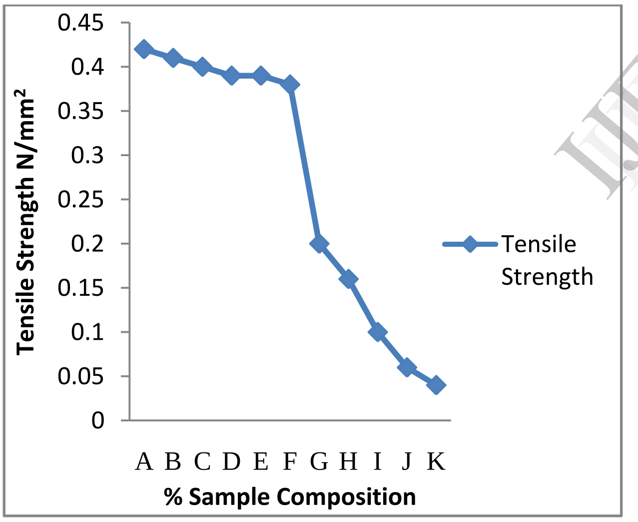

Fig.2 Effect of blend proportion on Tensile strength

In fig.3 it was observed that sample F having the best resistance to abrasion with the least value of percentage loss of 10.21% in 500Rev. and 7.69% in 200Rev.

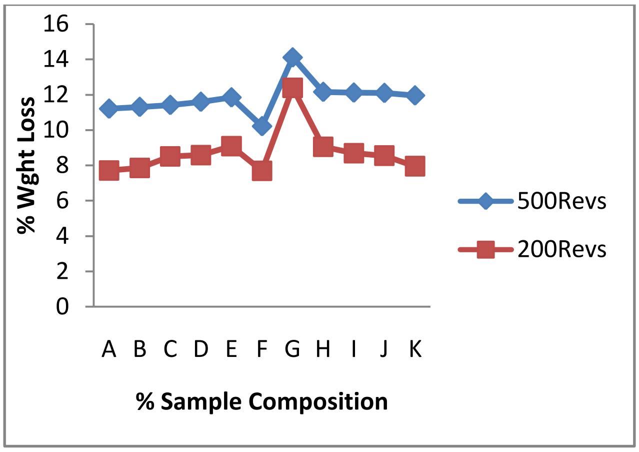

Fig.3 Effect of blend proportion on Abrasion resistance

CONCLUSION/RECOMMENDATION

Banana/Sugar cane fibre paper blend has the maximum tensile strength and tear resistance strength at higher percentage composition of the banana fibre in the blend. This was due to the long fibre length of banana fibre. For a better abrasion resistance paper, it is best using blend ratio F, because it has the least percentage weight loss to abrasion resistance.It was generally observed that samples with more banana fibre in the composition performed better in term of strength of the material. More research needsto be carried out on how to improve on the properties of sugar cane fibre for a better yield in the area of strength.

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