Utilization of Bagasse as Raw Material for the Production of Pulp and Paper in Nigeria

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ABSTRACT

This experimentation was carried out in an effort to search for raw materials to replace the present importation of long fibre pulp in Nigeria. Bagasse was macerated and the properties of its pulp were evaluated. Sample sheets of paper were produced using hand sheet method and were duly tested for tearing resistance, tensile strength and burst strength. The pulp has fairly long fibre length of 2.071mm. Its papers posses high tearing resistance of 1226.25mN and tear factor 125.00m^2 but low tensile strength of 6.50Nm/g and burst strength of 57.5kPa. Therefore its paper products can be used for writing and printing applications, but not suitable for wrapping and packaging..

INTRODUCTION

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. Nigeria with her three grounded paper mills is now an importer of paper and paper products. One of the causes of failure of the local pulp and paper industries has been the importation of long fibre pulp which consumes foreign exchange. Use of suitable local long fibre sources would provide for import substitution. Identifying local fibre sources will enhance the economic viability of the existing mills and probably lead to their revival. Saving in foreign exchange would be achieved by the reduction in the importation of paper and paper products to the country. Paper products use depends on the strength properties of the paper. Papers with high tearing resistance can be used for writing and printing applications. Those with high tensile strength and burst strength are good for wrapping and packaging. Also the strength of paper depends on the fibre length of the wood (Sven, 1965) and the method of pulping process used. The aim of this study is to experiment waste bagasse as useful raw materials for the production of pulp and paper in Nigeria.

MATERIALS AND METHOD

Bagasse chips were used as experimental samples. Pulping was done by maceration and the macerating chemicals were glacial ethanoic acid and hydrogen peroxide. The reagents were analytical grades of 0.1N, potassium permanganate ($KMnO_4$), 4N sulphuric acid (H_2SO_4), potassium iodide (KI) (1N and 10%), 0.1N sodium thiosulphate ($Na_2S_2O_4$) solutions, starch indicator solution and glycerol. The apparatus included handmade paper machine, ceramic mortar and pestle, wooden mortar and pestle, beakers (2000ml and 250ml), measuring cylinders (1000ml, 250ml and 25ml), 50ml burette, 25ml pipette, some conical flasks, stop watch, thermometer, plastic buckets, microscope, burst strength tester and the instron table model 1026.

Digestion by Maceration (Cold Cooking): Stems of bagasse was obtained from a farm in Raffin Gussan village, Kaduna state Nigeria. It was crushed and cut into chips of average size 25mm long with a matchet. Sample of the chips was weighed and kept in an oven for about 2 hours after which it was removed, cooled and weighed. It was put back in the oven for about 30 minutes and reweighed. The process was repeated several times until a constant weight was obtained and the moisture content of the chips was calculated. 150.86g dry weight of the chips was soaked in 1700ml of the mixture of glacial ethanoic acid and hydrogen peroxide in the ratio of 1:1 for seven days. The mixture was stirred thoroughly each day. 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. To determine the optimum maceration conditions, four samples of equal weight 11.85g of dry weight of bagasse were soaked in 150ml of the macerating liquor for 7,10,15 and 20 days.

Pulp Moisture Content Analysis: Sample of the pulp was weighed and kept in an oven for about 2 hours after which it was removed, cooled and weighed. It was put back in the oven for about 30 minutes and reweighed. The process was repeated several times until a constant weight was obtained and the moisture content of the pulp was calculated. The pulp yield was evaluated thus:

$$M = GW - DW \quad \text{.....(1)}$$

$$\%M = \frac{GW - DW}{GW} \times 100 \quad \text{..... (2)}$$

Where

M = moisture content (g or ml)
GW = green weight (g)
DW = dry weight (g)

Pulp Refining (Beating): The "accept" pulp was beaten using a wooden mortar and a pestle for about 20 minutes. The inner part of the mortar was covered with a nylon bag and the pestle was wrapped with a cellophane bag to avoid direct contact. At the end of the beating, the refined pulp was mixed with plenty water to a consistency of about 0.1%.

Sheet Formation: After thorough mixing a hand sheet former (mould) was dipped into the pulp suspension and raised out of the suspension. A woven mat of cellulose fibre was formed on the mould which was sun dried for about four hours. After drying the paper formed was carefully removed from the mould and then left on the sun for further drying.

Fibre Morphology Analysis: A pulp suspension was prepared with distilled water and the pulp slide was picked with needle dropper onto the slide. Two drops of glycerol (mounting reagent) were added to the pulp slide and then covered with cover glass. The slide was mounted on the compound microscope under the magnification of 10 objectives (total magnification 100). The fibre length and thickness were measured with the calibration factor of 9.7. Readings were multiplied by 9.7 in micrometre (μm) and the converted into millimetre (mm).

$$H = h \times 9.7\,\text{h} \quad \text{..... (3)}$$

$$D = d \times 9.7 \quad \text{..... (4)}$$

Where

H = fibre length (mm)
h = fibre length measured in microscope
D = fibre thickness (mm)
d = fibre thickness measured in microscope

Wood Kappa Number and Lignin Content: 0.5g dry weight of raw bagasse was soaked in 30ml of distilled water and grounded to paste with a ceramic mortar and pestle. 570ml of distilled water was added to the paste and stirred. A mixture of 75ml 4N sulphuric acid and 75ml 0.1N potassium permanganate was added to the paste, stirred and the temperature was maintained constant at 25^{o}C for ten minutes. After ten minutes 15ml 1N potassium iodide was added to the mixture and stirred. 25ml of the mixture was titrated against 0.1N solution of sodium thiosulphate to pale colour, two drops of starch indicator solution was added and the titration continued to colourless solution. The Kappa number and lignin content were calculated using Hussain et al (2002) method. The Kappa number and lignin content were evaluated thus:

$$\text{P-No} = 75 - \text{v} \quad \text{..... (5)}$$

$$\text{K-No} = \frac{P\_No \times f}{w} \quad \text{..... (6)}$$

$$\%L = K\_No \times 0.155 \quad \text{..... (7)}$$

Where
P-No = permanganate number
v = titre value (ml)
L = lignin content
K-No = Kappa number
f = correction factor (50%)
w= weight of raw wood sample mixed with distilled water (g)

Pulp Kappa Number and Lignin Content: 1.0g dry weight pulp was soaked in 30ml distilled water in a ceramic mortar and was grounded into paste with pestle. It was transferred into a 2000ml beaker and the volume was made up to1200ml with distilled water and stirred thoroughly. 40ml 4N sulphuric acid solution was added to the mixture and stirred. After five minutes 40ml 0.1N potassium permanganate was added and stirred. After another five minutes, 5ml 10% potassium iodide was added and stirred. The reaction temperature was taken and 25ml of the solution was titrated against 0.1N sodium thiosulphate to pale colour. Two drops of starch indicator solution was added and the titration continued to colourless solution. The titre value was read and recorded from which the Kappa number and the lignin content were evaluated thus:

$$P\text{-}No = 40 - v \quad \text{.....(8)}$$

$$\Theta = Tr - To \quad \text{..... (9)}$$

$$T = \theta\,[1.8] \quad \text{..... (10)}$$

(Rogers and Mayhew, 1981)

$$K\text{-}No = P\text{-}No - T \quad \text{..... (11)}$$

The Kappa number K-No is corrected to 50%

$$\%L = K\_No \times 0.147 \quad \text{.....(12)}$$

(James, 1980)

Where
Θ = temperature difference (^{0}C)
V = titre value (ml)
Tr = reaction temperature (^{0}C)
To = ambient temperature (^{0}C)
T = temperature (^{0}R)

Tearing Resistance Test: For conditioning, the sample sheets were left in the laboratory for two days before the test. The samples were prepared by cutting 10cm by 4cm of the papers formed. An initial tear was made to about half the length. The torn side was gripped to the upper and lower grips of the Instron Table Model 1026. The load cell amplifier controls were adjusted to 5 and then the control switches were pressed to start the test until the tearing was completed. The force required to tear the paper was read from a graph sheet in grams and converted to millinewtons.

$$T = m \times g \quad \text{..... (13)}$$

$$Tf = \frac{100 \times m}{G} \quad \text{..... (14)}$$

Where
T = tear resistance (mN)
m = tearing force (g) read from the graph
Tf = tear factor (m^2)
G = basis weight (g/m^2)
g = acceleration due gravity (m/s^2)

Tensile Strength Test: After conditioning as in tear resistance test, the sample papers prepared by cutting 15cm by 4cm. A load of 500g was placed on the load cell and the sample paper was gripped to upper and lower grips of the Instron Table Model 1026 in the laboratory mentioned above. 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 a graph and the tensile strength was evaluated thus:

$$Ts = \frac{BW}{b} \quad \text{..... (15)}$$

$$Tsi = \frac{Ts}{G} \quad \text{..... (16)}$$

Where

Ts = tensile strength (N/m)

BW = breaking weight (N)

b = width of the sample sheet (m)

Tsi = tensile strength index (g/m^2)

G = basis weight (g/m^2)

Burst Strength Test: For conditioning, the sample sheets were left in the laboratory for two days before the test. The sample paper was clamped over a diaphragm on the digital bursting strength tester in position using the screw. The motor drive was switched to the forward position and the paper was observed until it bursted and the motor drive was switched off while the reading was taking and recorded. The paper position was changed and the procedure was repeated, and more readings were obtained and recorded.

RESULTS AND DISCUSSION

The results of this investigation are presented and discussed below. The parameters investigated were chip moisture content of raw wood and pulp, optimum maceration time and pulp yield, Kappa number and lignin content, fibre morphology and strength properties of sample papers.

Maceration Analysis: The results of the analysis before and after maceration are presented on table 1. The moisture content of the chips was found on the average to be 14.14%. 150.48g of bagasse was soaked in 1700ml of the macerating liquor yielded a bath ratio of 11:1. The moisture content of chips for optimum maceration time was 13.50%. 11.85g dry weight of chips was soaked in 150ml of the macerating liquor yielded the bath ratio 12.5. The pulp moisture content was found to be 81.38%. This is required to compute the pulp yield. The Kappa number of the bagasse was found to be 89.600 and lignin content 13.67% which is less than the literature value which ranges from 18 .10% - 22.2% (James, 1980).

Optimum Maceration Time on Pulp Yield, Kappa Number and Lignin Content: To determine the optimum maceration time that yield the best quality pulp in terms of pulp yield, Kappa number and lignin content, four samples of equal weight of bagasse were macerated for 7, 10, 15 and 20 days with equal bath ratio. The results are presented in table 2. From these results, it can be deduced that the optimum period for complete maceration of bagasse is between 7 and 10 days as there is much decrease in pulp yield and insignificant change in lignin content after 10 days.

Fibre Morphology: The average fibre length of bagasse was found to be 2.071mm which is longer than the average fibre length in the literature 1.7mm (Sven, 1965). Its fibre thickness was found to be 0.02425mm. These results are presented on table 3. These properties depend on some factors which include maturity of the plant, soil conditions and geographical location (James, 1980). Their values determine the strength properties of the paper sheets produced from the source.

Mechanical Strength Properties of the Sample Sheets: The results of the strength properties of the sample sheets are presented on table 4. The average tear resistance for bagasse was found to be 1226.25mN which is greater than the TAPPI T414, which ranges from 500 - 700Mn (Internet, 2007a) as shown in figure 1. The tear factor was found to 125.00m2 which is greater than the minimum standard of The Nigeria Paper Mill, Jebba which is 120m^2 (NPM Lab. Manual, 1991) as shown in figure 2. Hence its paper products are good for writing, printing, corrugating medium and insulating board applications.

The breaking weight of bagasse was found to be 26.00N which is greater than the minimum standard of The Nigeria Paper Mill Jebba, 5.6 - 7.5N for all grades of her papers (NPM Lab. Manual, 1991) as shown in figure 3. However, the tensile strength index of bagasse papers was found to be 6.50Nm/g which is lower than TAPPI T494 which is 40 - 70Nm/g for Machine Direction (MD) and 20 - 40Nm/g for Cross Direction (CD) (Internet, 2007a) as shown in figure 4. The average bursting strength of bagasse was found to be 57.50k Pa which is lower than the minimum standard of TAPPI T403 which ranges from 250-300kPa (Internet, 2007a) as shown in figure 5. These values indicate that the paper products of bagasse are not suitable for wrapping and packaging applications.

Table 1: Maceration Analysis

Properties	GW (g)	DW (g)	M (g)	%M	B.R
Chips moisture content analysis	9.90	8.50	1.40	14.14	-
Maceration analysis of chips	175.32	150.48	24.84	14.14	11:1
Pulp moisture analysis	3.80	0.70	3.10	81.38	-
Chips moisture content optimum time	13.70	11.85	1.85	13.50	12.5:1

Key: GW = green weight, DW = dry weight, M = moisture content

Table 2: Optimum Time on Pulp Yield, Kappa Number and Lignin Content

Length of maceration	**Pulp yield (%)**	**Kappa number**	**Lignin content (%)**
7 day	45.57	12.83	1.89
10 gays	28.10	12.75	1.87
15 days	25.82	12.65	1.86
20 days	25.53	12.60	1.85

Table 3: Fibre Morphology

Parameter	Average	Lit. Value	L/T	Lit. L/T*
Fibre length (mm)	2.071	1.700	85.4:1	85:1
Fibre thickness (mm)	0.0243	0.02		

*Source (Hurter, 2006)

Table 4: Mechanical Strength of the Samples of Paper

Properties	*Bagasse*	NPM Jabba	TAPPI
Basis weight (g/m^2)	100.00	80 - 100	50-100
Tear resistance (mN)	1226.25	320 - 400	500 – 700
Tear factor (m^2)	125.00	120.00	30MD,40CD
Breaking weight (N)	26.00	5.6 - 7.5	30
Tensile strength index (Nm/g)	6.50	N/A	40-70(MD) 20-40(CD)
Burst strength (kPa)	57.50	N/A	250-300

Key: NPM = Nigeria Paper Mill, and TAPPI = Technical Association of Pulp and Paper Industries.

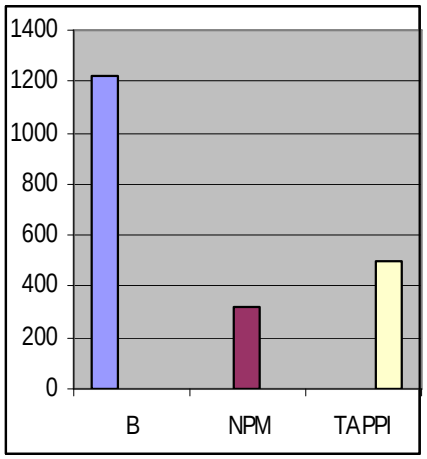

Figure 1: Tearing resistance (mN)

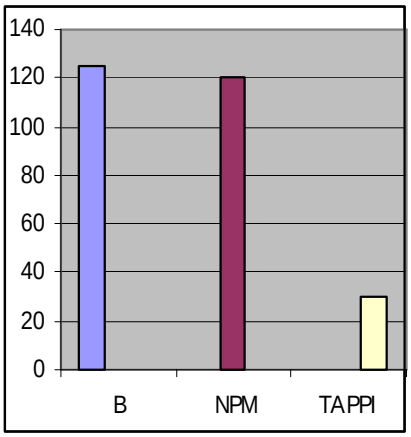

Figure 2: Tear Factor (m^2)

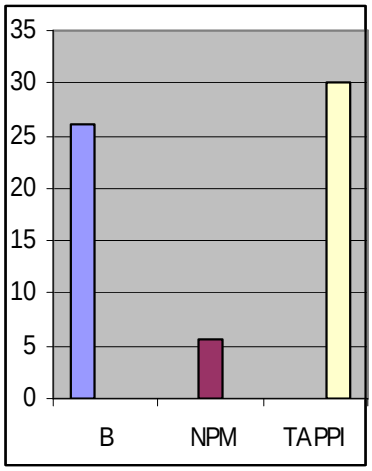

Figure 3: Breaking Weight (N)

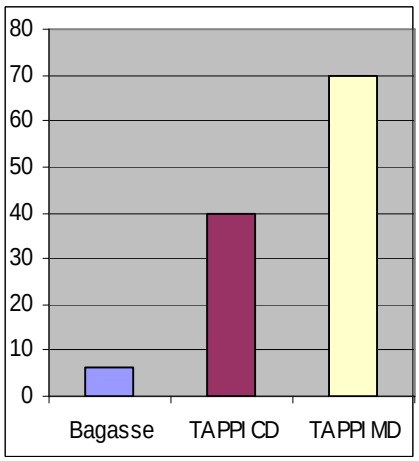

Figure 4: Tensile Strength Index (Nm/g)

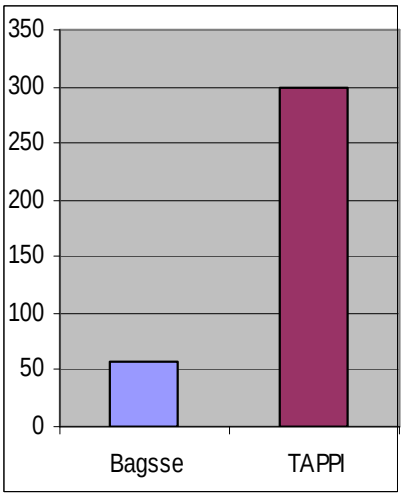

Figure5: Burst Strength (kPa)

Plate1: Sample of paper of bagasse

CONCLUSION

Bagasse was evaluated for the production of pulp and papers. It has fairly long fibre length and low lignin content suitable for paper making. Samples paper were produced and tested for mechanical strength properties. They exhibited standard qualities for tearing resistance above TAPPI T414 for all grades of papers except test liner, hence its papers can be used for writing, printing, corrugating medium and insulating board applications. Its papers exhibited standard qualities for tear factor and breaking weight above The Nigeria Paper Mill, Jebba standard for all her grades of paper. The results of tensile strength index and the bursting strength are below standard of TAPPI T494 and T403, thus indicating that they are not suitable for packaging and wrapping papers.

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