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Full Length Research Paper

Optimization of the fiber and physical properties of *Sterculia Setigera* as an alternative source of raw material for Pulp and paper making

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The fiber and physical properties of pulps and papers made from *Sterculia setigera,* a tropical hardwood specie and also an agricultural residue were investigated. The tree was sourced locally and then debarked. Thereafter, the debarked trunk was chopped into chips of average lengths ranging from 0.3cm to 0.6cm. These chips were gathered and then measured into weights in grammes of 100's. Variable percentage (20%, 40%, 60%, 80%) concentrations of sodium hydroxide (NaOH) were used to pulp different specimens of chips of fixed weights (100g), at a constant time of two (2) hours. The resultant pulps were bleached with 100ml of hydrogen peroxide, H_2O_2 and 5 spoons full of titanium oxide, TiO_4 to improved its brightness. Fiber characteristics and other physical properties of the pulps were obtained and hand-made writing papers were made from these pulps. Finally, different tests in accordance with the Technical Association of Pulp and Paper Industry (TAPPI), U.S.A were carried on the resultant papers and their results compared to those obtained in commercial writing papers. The results compares favorably with those stipulated by TAPPI (1990) and with properties of machine produced commercial writing papers available in Nigeria.

Keywords: *Sterculia setigera,* Pulp, Paper making, Handmade, Fiber, Ash.

INTRODUCTION

As stated in the Forest Industries Subsection of the third World Forestry Congress recommendation, held in Helsinki, Finland, 1949, that in order to enthrone sustainable wood-based forest Industry, there should be an urgent need to widen the sources of potential wood-based fibrous raw materials for Pulp and Paper Industries, by experimenting with tropical hardwood in pulp and paper making (Anon, 1955 : Miller, 1975 : Schniewind, 1989).

More so, available records indicate that the supply of industrial hardwood is far short of demand in Nigeria (World Bank, 1992). Harvesting pressures on forest in order to meet industrial demand, has in the past resulted in cutting above the Annual Allowable Cut (AAC) and consequent environmental degradation [(Anichukwu, 1990 : Schniewind, 1989 : Shenwood, 1983). *Sterculia setigera* is a tropical horticultural hardwood species widely grown for its fruits in Sub-Saharan Africa. It is classified under genus *sterculia* and family *malvaceae* (Boutelje, 1980 : Cassey, 1980). The tree is widely grown in the rainforest and savanna vegetation belts of Nigeria. It grows to merchantable height, 23m force bole. The wood fibrous raw materials, had at best only been used for fire wood and often burnt, and ashes incorporated into ingredients for local soap making. In view of the wide

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spread planting of this species, finding an efficient industrial outlet for the fiber, will be an appropriate technology. Available records are that Nigeria's capacity to meet her industrial fiber needs by the year 2020 will be in serious jeopardy unless alternative fiber sources and sustainable industrial wood management is enthroned (Anon 1971 : Nnabuife and Ikwueze, 1993).

The use of woody and/or agricultural residue for meeting the fiber needs of the wood-based composite Industry is widely practiced (Nnabuife and Ikwueze, 1993 : Onuorah, 2001).

However, the technical property requirements for optimal and efficient production will vary depending on industry and it's because of this that it is essential to carry out empirical study to understand the characteristics of a particular timber/lignocelluloses species. This is because wide variabilities are known to exist between different parts of same species. There is therefore a compelling need to understudy the mechanical properties of pulps and paper made from *Sterculia setigera*, an agricultural residue, as an industrial fiber source.

MATERIALS AND METHOD EXPERIMENTS

The experiment was carried out in two (2) stages stated thus:

- Determination of the fiber and physical characteristics of the pulp and then noting the optimal pulping conditions using variable sodium hydroxide (NaOH) concentrations.
- Production of hand made paper from the resultant pulp.

Determination of the fiber and physical characteristics of the pulp and then noting the optimal pulping conditions using variable sodium hydroxide [NaOH] concentrations.

Apparatus used

- Automated Optical Analyzer
- Electric Weighing Balance
- Oven
- Dessicator
- Earthen ware pot
- Measuring cylinder [cm]
- Test specimen
- Silicate dish
- Stirrer
- 100ml Beaker
- Plastic Bucket
- Pressing Iron
- Calico material i.e. white absorbent cloth

Reagents Used

- Nitric Acid, this was used during ashing to speed up the reaction and burn off organic matters quickly.
- Sodium Hydroxide pellets, used during the pulping
- Hydrogen peroxide, H_2O_2 used to bleach the pulp.
- Titanium oxide, TiO_4, used to improve the whiteness of the pulp
- Water, H_2O.

Pulping of Specimen

0.2g of sodium hydroxide, NaOH, pellets were dissolved in 100mL of water in a beaker, to produce 20% of NaOH concentration.

A fixed sample (100g) of specimen was properly fed into and earthen ware pot and 20% NaOH concentration was added to it and stirred. The mixture was then placed on a hot plate at 100^0C and allowed to digest fully. The time taken for this was 2 hours. It was recorded and kept fixed for other variations of NaOH concentrations. The pulp obtained (slightly brownish in color) was bleached by adding 100mL hydrogen peroxide, H_2O_2, and about five (5) spoon-full of titanium oxide, TiO_4, in a plastic bucket. This whole mixture was then left for 24 hours to enhance proper brightness of the pulp, the bleached pulp was then washed with about seven (7) liters of water in a bucket.

These procedures were repeated for 40%, 60% and 80% NaOH concentration.

Finally, the yield percent of the pulp obtained was calculated using the relations.

$$Pulp\ yield = \frac{Weight\ of\ oven\ dry\ pulp}{Weight\ of\ oven\ dry\ specimen}$$

Fiber characteristics or fiber length of pulp.

A sample of the pulp specimen derived from 20% NaOH was dropped on the slide of an Automated Optical Analyzer. It was then viewed from the microscope attached in the analyzer. The length of the fiber in the pulp was then read – off from the scale provided in the analyzer. This value was then recorded. The same procedures were carried out for samples of pulp made from 40%, 60% and 80% NaOH concentrations, and their corresponding fiber lengths recorded respectively.

Determination of moisture contents

A fixed weight of pulps specimen derived from 20% NaOH concentration was oven dried at 105 ± 2^0C in ventilated oven for 24 hours. At the end of this period, the dried oven pulp was quickly weighed and returned to the oven until two consecutive readings indicated no further weight loss. This was taken as the oven dry weight of the pulp specimen.

The moisture content in percentage was then calculated from the relation below:

$$MC(\%) = \frac{W_w - W_d}{W_d} \times 100$$

Where, MC = Moisture content

W_w = Initial weight of the Pulp specimen

W_d = Oven dry weight of the pulp

These whole procedures were repeated for the same weight of pulp specimen derived from 40%, 60% and 80% NaOH concentrations, respectively.

Determination of the ash contents of specimens

In doing this, a given weight of the specimen derived from 20% NaOH concentration, oven dried; was placed on a weighted empty silicate dish and then reweighed. 5mL nitric acid was added to the specimen (this helped to bring the specimen into ash by burning off the organic matters). This whole arrangement was then placed in a oven at temperature of 105°C for about 2 hours, until it was completely ashed. It was then removed from the oven and allowed to cool undisturbed over a 24 hours period. The ash content was then calculated from the expression.

$$Ash\ Content(\%) = \frac{B_1}{B_2} \times 100$$

Where B_1 = Weight of Ash and B_2 = Weight of Oven Dry Specimen

These procedures were repeated for pulp specimens derived from 40%, 60% and 80% NaOH concentrations respectively.

Determination of specific gravity of pulps specimen

A give weight of the pulp specimen derived from 20% NaOH concentration was first oven dried. This was done by placing the specimen in an oven at about 100°C for 3 hours and weighed at specific intervals until its weight became constant. The specimen was t hen removed from the oven, cooled in a desiccators and weighed. The volume of the specimen was determined by Archimedes principle, that is, a small sample of the over dry specimen was weighed. Water was poured into a measuring cylinder and the volume rerecorded. The oven dried specimen was then added to the water and the extent to which the level of water increased was recorded. The density of the oven dry specimen was then obtained from the relation

$$\rho_{OVEN\ DRY\ SPECIMEN} = \frac{Weight\ of\ oven\ dry\ specimen}{Volume\ of\ oven\ dry\ specimen}$$

Finally, the specific gravity of the specimen was obtained from the relation below:-

$$G = \frac{\rho_{OVEN\ DRY\ SPECIMEN}}{\rho_{WATER}}$$

Where $\rho = density$

$G = Specific\ gravity$

These procedures were then repeated for pulp specimens derived from 40%, 60% and 80% NaOH concentrations respectively.

Production of handmade paper

Bleaching

As reported earlier during the pulping process, 100ml of hydrogen peroxide was added to the unbleached pulp in a plastic bucket and left for about 24hours. Lignin is the dominating source of color in the unbleached pulp, but on bleaching, the lignin and other discoloring substances were brightened or removed. The bleached pulp was later washed with about 7litres of water in a bucket until it is neutral to litmus. The color of the bleached pulp becomes whitish

Sizing

6g of commercial starch was made from 20% sodium hydroxide solution. These was then added to the bleached pulps

Screening/Drying

The pulp mixture was poured on a handkerchief placed on a tray. The handkerchief was carefully raised up, stretching it properly to see that pulp fills every space for proper interlocking of the cellulose fiber after which it was then dried

Pressing and Calendaring

The pulp on the handkerchief was covered with an absorbent calico cloth and placed on and hydraulic press,

Table 1. Percentage Pulp Yields of Specimen.

NaOH(%) concentration	Weight of oven dry pulp (g)	Weight of oven dry specimen (g)	Pulp yield (%)
20	64	100	64
40	62	100	62
60	61	100	61
80	58	100	58

Table 2: Mean fiber lengths obtained from specimen, pulped at different NaOH concentrations.

NaOH(%) concentrations	Fiber length (cm)
20	0.58
40	0.58
60	0.59
80	0.60

Table 3: Moisture Contents of Specimen pulped at different NaOH concentrations.

NaOH(%) concentrations	Initial weight of pulp Ww (g)	Oven dry weight Wd (g)	Moisture content (%)
20	115	103	11.65
40	115	102	12.75
60	115	101	13.86
80	115	100	15.00

after which it was kept under the sun to dry up. Finally, the paper was calendared using a pressing iron to achieve smoothness.

Product Testing

Three physical property test were carried on the handmade papers produced and these were done in accordance with the procedures stipulated by the Technical Association of Pulp and Paper Industry (TAPPI, 1990) USA. The test includes caliper/thickness test, burst strength and moisture absorption tests. The tests were carried on each sheet of papers produced from the resultant pulps of 20%, 40%, 60% and 80% NaOH concentrations. The results were finally compared with that of commercial papers.

RESULT AND DISCUSSIONS

The Results are presented in tables 1 to 8 below.
The table above represents the average percentage pulp yields obtained from pulping the specimen (ukwa trunk) using different NaOH Concentrations.

Tests Results

DISCUSSIONS

From table1 it can be seen that pulp yield (a property which gives the relative return of pulp compared to the raw chips used, wt/wt basis) increase as NaOH decreases and vice versa. This is in keeping with the range reported in the literature for semi-chemical pulps, (Boutelje, 1980 : Timmell, 1988). It is pertinent to note that the pulp yield is a function of paper thickness produced. The more the pulp, the thicker the paper (Anon, 1955).

Considering table 2, the mean fiber length as reported is within the range of hardwoods. The fiber lengths as reported represent the average of twenty fiber measurement selected at random. The variable fiber lengths with concentrations of NaOH used is not sustained by any scientific facts or theory. However, one possible explanation is that out of inexperience, the random selection of chips from the trunk was not effective and thus error emanating from growth related of variability in trees was introduced.

From table 3, it could be observe that there were variations in the moisture contents of the specimen for

Table 4. Ash Contents of Oven Dry specimen as pulped under various NaOH concentrations.

NaOH(%) concentrations	Weight of Ash (g)	Weight of oven dry specimen (g)	Ash Content (%)
20	17.0	100	17.0
40	15.5	100	15.5
60	14.0	100	14.0
80	12.0	100	12.0

Table 5. Specific Gravity of Specimen, pulped at different NaOH concentrations

NaOH (%) conc.	Density of oven dry specimen (g/cm^3)	Density of water (g/cm^3)	Specific gravity
20	0.29	1.00	0.29
40	0.28	1.00	0.28
60	0.28	1.00	0.28
80	0.27	1.00	0.27

Table 6. Mean caliper/thickness of handmade paper obtained from various NaOH concentrations.

NaOH(%) concentrations	Thickness (mm)
20	0.40
40	0.30
60	0.19
80	0.10
Commercial paper	0.25

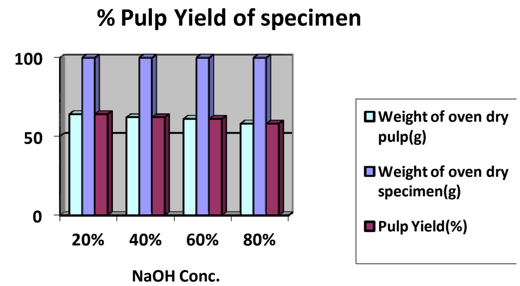
Table 7. Burst Strength of handmade paper obtained from various NaOH concentrations.

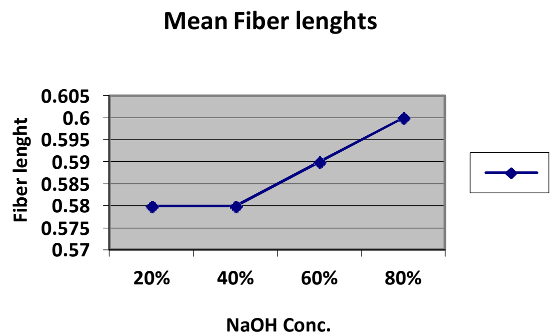
NaOH(%) concentrations	Burst Strength (Nm^{-2})
20	4.89
40	3.89
60	3.20
80	2.10
Commercial paper	3.60

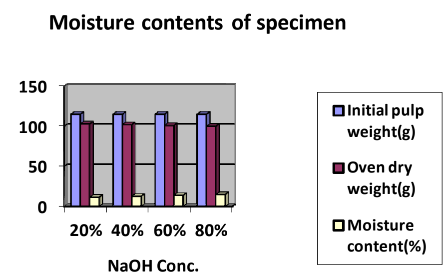
Table 8. Moisture absorption of handmade paper obtained from various NaOH concentrations.

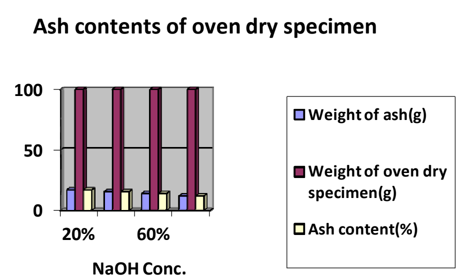
NaOH(%) concentrations	Moisture Absorption (g)
20	0.04
40	0.09
60	0.14
80	0.20
Commercial paper	0.12

the various concentration of NaOH. As the concentration of NaOH increases, the percentage moisture content also increases. The mean ash contents for the pulps produced using different NaOH concentrations is presented in table 4. From the table, there is a marginal decrease in ash content as the concentration of the chemical used in pulping increases. One possible explanation is that lignin and other peptic substances removed from the middle







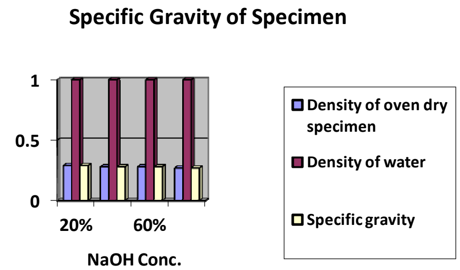


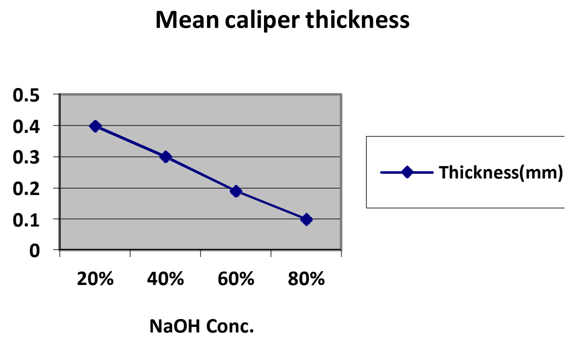
lamellae/ primary wall tends to contain more of the earthy substances. On closer observation, however, it does appear that the average ash content recorded is above the average reported for wood and lignocelluloses materials. One possible explanation is the carbonization process was incomplete and thus, the recorded ash content contains some other impurities. However, it is not unusual to record deviations away from average and thus, further work is required to determine conclusively the average ash content of *sterculia setigera*.

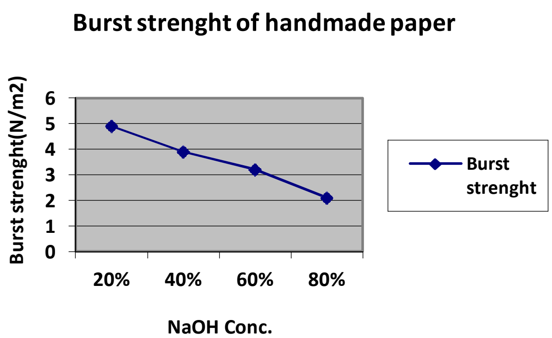
Table 6,7 and 8 shows the test results and it can be seen that when compared to those of commercial papers, the optimal pulping conditions were achieved at NaOH concentrations range of between 40% and 60%.

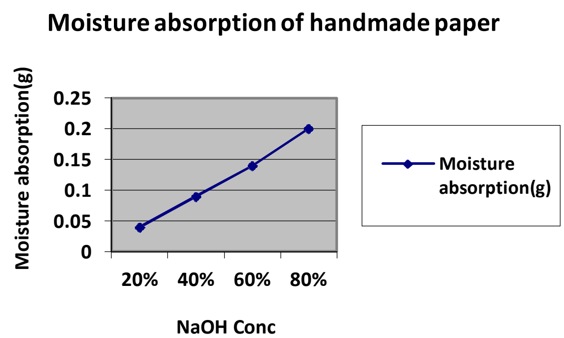
CONCLUSION AND RECOMMENDATION

The study has shown that pulp and paper could be produced from *sterculia setigera* a tropical hardwood species and an agricultural residue. The quality of pulp and paper produced, especially by the 40% and 60% NaOH concentrations gave technical properties that are close to that of commercial pulps and papers.









Additionally, pulps produced from a process as used in this study will be suitable for production of commercial writing papers, corrugated boards, fiber boards and some industrial paper.

RECOMMENDATION

Based on the findings, on the course of the project work and having produced good quality hand-made papers from indigenous ukwa tree, we here by recommend that:

Farmers should be encouraged to plant this species of trees to ensure the quantities of its supply for industrial paper productions, even when other hardwood species fall in quantities.

REFERENCES

Anichukwu RC (1990). IT Report on Pulp and Paper and making at Nigeria Paper Mill Jebba, 1990.

Anon (1955), The Dictionary of Paper, 3rd Edition. American Paper and Pulp Association, U.S.A.

Anon (1971). TAPPI T20505 71, Forming Hand Sheets for Physical Tests of Pulp

Boutelje JB (1980). Encyclopedia of world timbers, names and technical literature. (Ency W Timber)

Cassey JP (1980). Pulp and Paper Chemistry and Chemical Technology, 2nd Edition, pp 985 – 989.

Miller KT (1975). Consulting Engineers World Straw Conference, Eugen Oregun 1975

Nnabuife ELC, Ikwueze WO (1993). Paper Recycling, Nigeria Scene four "p" News, Volume 5.

Onuorah OE (2001). Preliminary Investigation of the Potential of Six Nigerian Grown Hardwood Species as sources of fiber for the Pulp and Paper Industry (Journal of Agricultural Technology (JAT).

Schniewind AP (1989). Concise Encyclopedia of Wood and Woode based methods, 354 pp.

Shenwood PM (1983). Project Evaluation in the Paper Industry Pulp and Paper Magazine, Canada.

Timmell TE (1988). Encyclopedia of Material Sciece and Engineering, Volume 7 (T-Z) (pg 5403-5408), U.S.A.