POTENTIALS OF AGRICULTURAL WASTE AND GRASSES IN PULP AND PAPERMAKING

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ABSTRACT

Potentials of some agricultural waste and grasses were investigated. Potassium hydroxide from wood ash was used as alkali for pulping. Results from visopan Microscope showed that banana stalk has the highest fibre length of 2.60 mm and Bahaman grass has the least fibre length of 0.85 mm. Runkel Ratio (RK) for banana stalk, banana leaf, giant bluestem, gamba grass and bagasse was 0.8 (RK<1) while pineapple leaf and maize stalk have Runkel ratio of 0.9 (RK<1). Peel from maize cob and Bahaman grass have Runkel Ratio of 1 (RK=1). Calculated fibre derivatives indicated that the non wood raw materials were good in pulp and papermaking.

Key words: *Non-wood fibre, fiber length, papermaking, lye, paper and pulp.*

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INTRODUCTION

The manufacture of pulp and paper is basic to education, printing, publishing and numerous packaging industries. Paper is widely used in the offices for writing, printing documents, and photocopying. At home, paper is used to clean, to dry things, and for many other purposes. Paper remains the dominant and essential vehicle of modern communication (MBendi, 2001). In summary, paper is one of the most versatile and common products of modern societies (Garbony, 2005).

Papermaking is one of the oldest crafts and one of the most modern industries. In its technical form, paper is an aqueous deposit of any vegetable fiber in the sheet form. The word paper comes from the Latin world "Papyrus" (*Cyperus papyrus*), a plant native to the Nile valley, which the Egyptian made into sheets that could be used to write on. This is known to have been used from 3500 B.C to 900 A.D (Edward, 1982).

Paper consists of a web of pulp fibres derived from wood or other plants from which lignin (complex organic materials that binds together fiber in trees and wooden plants) and other non-cellulose components are separated by cooking them with chemical at high temperature. In the final stages of papermaking, aqueous slurry of fibre components and additives are deposited on wire screen and water by gravity, processing, suction and evaporation (Biermann, 1993).

The paper industry is a forest-based industry. Depleting forest cover is a major cause of concern today because of the adverse environmental implication of the depletion (Vivek and Maheswari, 1998). Now, because of adverse effects of deforestation and the high cost of wood pulp, a number of countries are turning back to other sources of fibre. In 1992, 45 countries produced non wood paper, accounting for 9 percent of the world's paper supply. Studies have shown that the production process of paper from non-wood fibre is significantly less expensive than from wood fibre (Weston, 1996). Sam, (2004) stated that the world consumption of paper has grown four hundred percent in the last 40 years. He also said that the world consumes about 300 million tons of paper each year. Currently, global papermaking fibre consumption is projected to increase from about 300 million tones from 1998 to about 425 million tones by the year 2010 (Pande, 1998).

The purpose of this study was to make paper from non-wood plants, determine the Runkel Ratio of the macerated fibres of selected non-wood plants used as raw materials in papermaking, and examine the surface properties including colour and smoothness of handmade paper from the non-wood plant material.

MATERIALS AND METHODS

The Study Area

The research was conducted at the University of Agriculture Abeokuta, Ogun State. The pulping process was carried out at the Wood Laboratory in the Department of Forestry and Wildlife Management of the institution.

The Materials Used in the Production Process

The materials used in this research, were used by Douglas (1997) and were collected within the University compus, they include the following: Dianna Machine 13,00W used for crushing the non-wood raw materials, Honda GN60 WD Petrol Engine and miller used for grinding the material into pulp, two stands each for holding a clay pot, and a large table for spreading the sheets of papers produced. Non-wood raw materials were: giant bluestem (*Andropogon tectorum Scum. & Thonn.),* gamba grass *(Andropogon gayanus Kunth var. gayanus),* bahamas grass (*Cynodon dactylon (Linn.)Pers,* bagasse (*Sacchaum offinarum* L.), pineapple leaves (*Ananas comosus L. Merr.*)*,* maize straw (*Zea mays L*), peel from maize cob (*Zea mays L*), banana stalk (*Musa paradisiaca L*), banana leaf, (*Musa paradisiaca*) and Waste paper. Other materials include a cutlass, three plastic buckets, rubber gloves and safety goggle. Three bags of wood ash, four hundred litres of rainwater, two clay pots of 15kg each used for lye production. Two plastic pots (60 litres each) for collecting the lye produced, a plastic pot of 120 litres for storing the lye produced, an aluminum pot, and a framed screen for lifting sheet of pulp out of bowl (a mould). A smooth clean surface to hold the paper during final stages of drying, a pocketknife to help lift sheets of dry paper from the surface, a press, used to expel water mechanically fromed the freshly form paper, and small plastic bucket, bowl for transferring pulp and water.

Lye Production

Two clay pots perforated underneath weighing 15kg each were suspended by tables with round holes at their centers. A layer of gravel was put over the holes at the bottom of the pot, and then a layer of straw was put over the gravel. The rest of the pot was filled with 25.5kg of wood ash and 50 litres of rainwater was poured. The mixture was left to drain overnight.

Pulp Making from Plant Materials

Papermaking from non-wood materials requires step-by-step process. The pulping process steps as used by Anonymous (1998) and Douglas (1997) are shown in the chart below:

Collection of Raw Materials
↓
Sorting and dusting of the Materials
↓
Chopping of the Raw Materials
↓
Crushing of the Raw Materials
↓
Soaking of the Raw Materials in water
↓
Boiling the Raw Materials with Lye
↓
Grinding of the Raw material into Pulp
↓
Sheet Formation
↓
Couching of the formed sheets of Paper
↓
Drying of the paper
↓
Pressing/Drying
↓
Cleaning
↓
Cutting and Trimming of the paper

Figure 1. Chart showing the production Process of Paper from Non Wood Raw Materials

Papermaking from waste papers

Waste papers were cut into small pieces, about 2-3 cm on a side and the paper pieces were soaked in water overnight. The soaked paper was grinded with water for about 20 minutes, and the mixture (Slurring) was used to form recycled paper.

Laboratory Analysis

The measurement of fibre length and fibre diameter was carried out at the Wood Anatomy Laboratory of Forest Product research Division at Forestry Research Institute of Nigeria (FRIN) Ibadan. Cores were taken from eight samples of non-wood fibres. Each core was mildly macerated in a mixture of equal volume of glacial acetic acid and Hydrogen peroxide in the ratio of 1:1. The hydrogen peroxide acts as an oxidizing agent that bleaches the raw material's colour to complete white, while the glacial acetic acid acts as cooking medium, which softens the wood material.

Each portion of the materials' samples were put in a separated test tube containing the solution and kept in an oven for hours at temperature of 105^{o}C. After maceration, the cooked samples were washed several times with water, crushed with spatula in the test tube and were later shaken to separated the fibres. The separated fibres per sample in each test tube were mounted on microscope slide and examined under a Leitz Sterrogram microscope with a tracer reflector. The tracer reflector projected the magnified and transparent fibres and the fibres were viewed and traced using X3.2 eyepiece for fibre length, and X25 eyepiece for the fibre diameter. Five fibres each from the materials were randomly selected and traced.

Determination of Fibre Quality for Pulp and Papermaking

The fibre quality for pulp and papermaking can be determined by Runkel ratio (Runkle, 1952, Anonymous 1955) as showed in the formula below:

$$RK = \frac{2 \text{ x Wall Thickness of fibre } \{2w\}}{\text{Lumen Width of fibre } \{Lu\}}$$

This is the Runkel ratio (RK)

When, RK < or = 1 the fibre is good (pulpable), RK < 1 the fibre is very good (highly pulpable), and RK > 1, the fibre is not good for pulping.

Important criteria in papermaking can be determined using the following five equations (Kırcı, 2006):

Felting rate = Fiber length ÷ Fiber diameter

Elasticity coefficient (%) = Lumen diameter ÷ Fiber diameter×100

Rigidity coefficient (%) = Cell wall thickness ÷ Fiber diameter ×100

Runkel index = Cell wall thickness ×2 ÷ Lumen Diameter.

F ratio (%) = Fiber length ÷ Cell wall thickness ×100

RESULTS AND DISCUSSION

The results of the research show that giant bluestem, bagasse, maize stalk, Peel from maize cob, bahamas grass, gambagrass, pineapple leaf, banana stalk, banana leaf and waste paper can be utilized in the production of handmade paper.

Analysis of Fibre Dimension of Non Wood Raw Materials

Table 1 shows the identified non wood raw materials and their parts used in this research, while Table 2 shows the detailed analysis of the fibre characteristics of each of the raw materials used in the papermaking. Banana stalk has the highest fibre length of 2.60 mm and Bahamas grass has the least fibre length of 0.85 mm. The Runkel Ratio for banana stalk, banana leaf, giant bluestem, gambagrass and bagasse were 0.8 (RK<1). This shows that the raw materials are very good for paper making (pulpable). Pineapple leaf and maize stalk have Runkel ratio of 0.9 (RK<1). This means that they are equally good for papermaking. Peel from maize cob and Bahamas grass have Runkel Ratio of 1 (RK=1). This means that they are also good for paper making. A bar chart is used in Figure 1 to illustrate the fibre lengths of the various raw materials.

Table 1. Fibre Collection Record

Plant Common Name	Botanical Name	Plant Family	Date Collected	Parts of Plants Used	How Plants were Collected	Where Harvested	Weight of Dried Fiber (g)
Giant Bluestem	*Andropogon tectorum*	Gramineae	2006	Straw and leaf	Harvested from stand	Unaab's Compound	800
Gamba grass	*pogon gayanus*	Gramineae	2006	Straw and leaf	Harvested from stand	Unaab's Compound	800
Bahaman grass	*Cynodon dactylon*	Gramineae	2006	Whole plant	Collected as waste	Unaab's Compound	800
Bagasse	*Sacchaum offinarum*	Gramineae	2006	Residue from stalk	Collected as waste	Some Homes	400
Pineapple	*Ananas comosus*	Bromeliacae	2006	Leaf	As waste from vendors	Camp Abeokuta	400
Maize	*Zea mays*	Gramineae	2006	Stalk and Peel from cob	As waste from AMREC's farm UNAAB	Unaab's Compound	800
Banana	*Musa paradisiacal*	Musaceae	2006	Stalk and leaf	As waste from AMREC's farm UNAAB	Unaab's Compound	800
Waste paper	-	-	2006	-	As waste paper	Unaab's compound	800

Source: Field Survey, 2006

Table 2. Morphological properties of Non wood

Material	Mean Fibre Length (mm)	Runkel Ratio 2w/L	Felting Rate	Elasticity Coefficient	Rigidity Coefficient	F ratio
Giant bluestem	2.30	0.8	82.14	42.86	17.86	46.00
Gambagrass	2.29	0.8	81.79	42.86	17.86	45.80
Bahaman grass	0.85	1.0	38.64	54.55	27.27	17.00
Bagasse	1.91	0.8	83.04	52.17	21.74	38.20
Pineapple leaf	2.37	0.9	91.15	50.00	23.08	39.50
Maize straw	1.92	0.9	71.11	48.15	22.22	32.00
Peel from maize cob	1.90	1.0	79.17	58.33	29.17	27.14
Banana stalk	2.60	0.8	113.04	52.17	21.74	52.00
Banana leaf,	1.35	0.8	61.36	54.55	22.27	27.00
Waste paper.	-	-	-	-	-	-

Source: Laboratory Analysis, 2006.

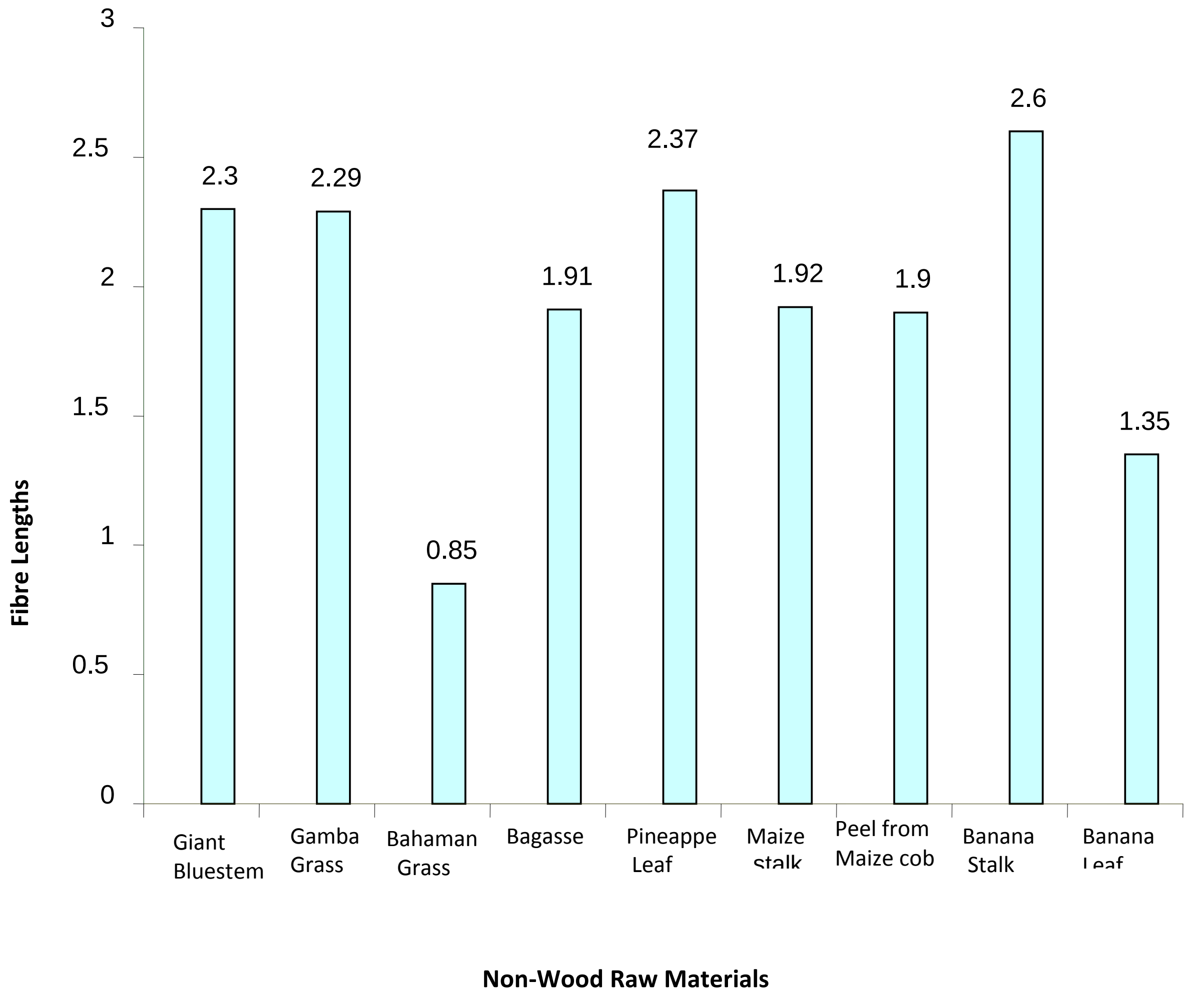

Figure 1: Bar Chart Showing the Fiber Length of the Raw Materials

Table 3. Fibre Preparation Record

Accessment	Fibres									
	Giantbluestem	Gamba grass	Bahama Grass	Bagasse	Pineapple Leaf	Maize Straw	Peel from Maize cob	Banana stalk	Banana Leaf	Waste Paper
Availability of the material	Abundant	Abundant	Abundant	Not Abundant	Not Abundant	Abundant	Abundant	Abundant	Abundant	Abundant
Precooking Preparation	Crushed in pieces and soaked overnight in water	Crushed in pieces and soaked overnight in water	soaked overnight in water	soaked overnight in water	Cut into ½ - inch pieces and soaked overnight in water	Cut into ½ - inch pieces and soaked overnight in water	Cut into ½ - inch pieces and soaked overnight in water	Cut into ½ - inch pieces and soaked overnight in water	Cut into ½ - inch pieces and soaked overnight in water	Cut into ½ - inch pieces and soaked overnight in water
Alkali	Lye	Lye	Lye	Lye	Lye	Lye	Lye	Lye	Lye	Lye
Weight of Alkali (Li)	16	16	16	12	16	16	16	16	16	-
Weight of Sample (g)	800	800	800	400	400	800	800	800	800	800
Period of Soaking	Overnight	Overnight	Overnight	Overnight	Overnight	Overnight	Overnight	Overnight	Overnight	Overnight
Time of Cooking(Hrs)	2	2	2	2	3	2	2	2	2	2
Time Rising (Mins)	10	10	10	5	5	10	10	10	10	10
Beating of fibre	Grinding machine	Grinding machine	Grinding machine	Grinding machine	Grinding machine	Grinding machine	Grinding machine	Grinding machine	Grinding machine	Grinding machine
Time of Grinding Fibre (Mins)	30	30	30	20	40	25	20	20	20	20
Additives	None	None	None	None	None	None	None	None	None	None
Comments on Grinding	Messing and difficult	Messing and difficult	Messing and difficult	Messing and difficult	Messing and difficult	Messing and difficult	Messing and difficult	Messing and difficult	Messing and difficult	Messing and difficult
Fiber Storage	Used immediately	Used immediately	Used immediately	Used immediately	Used immediately	Used immediately	Used immediately	Used immediately	Used immediately	Used immediately

Source: Field Survey, 2006

Table 4. Sheet Formation, Pressing and Drying Record

Paper	Giant Bluestem	Gamba grass	Bahaman grass	Bagasse	Pineapple	Maize Straw	Peel from Maize cob	Banana stalk	Banana Leaf	Waste Paper
Sheet Formation Method	Western Style	Western Style	Western Style	Western Style	Western Style	Western Style	Western Style	Western Style	Western Style	Western Style
Formation Comments	Pulp dried quickly	Pulp dried quickly	Pulp dried quickly	Pulp dried slowly	Pulp dried slowly	Pulp dried slowly	Pulp dried slowly	Pulp dried slowly	Pulp dried slowly	Pulp dried Quickly
Couching	Couched unto felt	Couched unto felt	Couched unto felt	Couched unto felt	Couched unto felt	Couched unto felt	Couched unto felt	Couched unto felt	Couched unto felt	Couched unto felt
Pressing	A roller	A roller	A roller	A roller	A roller	A roller	A roller	A roller	A roller	A roller
Drying	Sun Drying	Sun Drying	Sun Drying	Sun Drying	Sun Drying	Sun Drying	Sun Drying	Sun Drying	Sun Drying	Sun Drying
Sizing or Finishing	None	None	None	None	None	None	None	None	None	None
Sheet of Paper	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4
Quality of Sheets	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Appearance	Smooth	Visible Fiber Bundle	Smooth	Smooth	Tough	Smooth	Visible Fiber Bundle	Visible Fiber Bundle	Smooth	Smooth
Average weight of Paper (gms/m^2)	15.46	14.17	13.62	10.20	10.00	19.68	22.29	8.98	17.61	28.7
Flaw Characteristics	Dirt	Dirt	Uneven sheet formation	Crinkling	Air bubble & Crinkling	Dirt & Crinkling	Crinkling	Air bubble & dinged corner	Crinkling	Dirt

Source: Laboratory Analysis, 2006

The non-wood raw materials used in this research were very abundant around the University community except bagasse and pineapple leave that were collected outside the institution. That was why only 400g was used in the experiment.

The sheets of paper were sun dried. It was observed that giant blue stem paper, gamba grass paper, bahama grass paper and recycled paper dried quickly. While paper of other materials dried slowly. The drying is mainly due to the fineness of the pulp and nature of the material. The papers wrinkled under intense sun drying. Therefore, solar driers could speed up this process, reduce paper wrinkle and reduce the amount of space needed. Proper pressing and smoothening of the surface of the paper was done by means of a roller (a bottle).

Shrinkage of paper during drying was high in pineapple leaf paper, medium in banana stalk and low in Bahama grass paper, maize stalk paper, bagasse paper, and giant bluestem paper.

Visual evaluation of the handmade paper shows that the colour of the handmade paper varied from one material to another. Banana stalk paper was light purple, pineapple leaf paper and banana leaf paper were light brown and bagasse paper was milky. Giant bluestem paper, maize stalk paper and peel from maize cob paper and were light yellow while, bahama grass paper was light green in colour

The texture of banana stalk paper and pineapple leaf paper were coarse, maize cob peels paper and bahama grass papers have rough texture. The texture of bagasse paper and maize stalk paper were smooth while the texture of giant bluestem paper, banana leaf paper were smooth and uniform. The texture depends on the nature of the material and how well the material was grinded.

The hand sheet quality of banana stalk paper and pineapple leaf paper were very tough with high resistance to tear. That of giant bluestem paper, bagasse paper and maize stalk paper were smooth. Peel from maize cob paper, Bahama grass paper and gamba grass have visible fibre bundles. Handed sheet quality and shrinkage of the paper depend largely on the nature of the raw material used.

Some flaws were observed on the papers produced. Dirt was seen on giant bluestem paper and gamba grass paper. This could be due to stain resulting from improper cleaning of the mould. Crinkling was seen on bagasse paper, pineapple leaf paper, maize paper and banana paper. This may be due to poor handling of the pressed sheets. Uneven sheet formation was seen on Bahama grass paper. Dinged corner and air bubbles were seen on banana stalk paper, and

pineapple paper. This could be as result of poor handling of the sheets of paper during couching. These flaws could be reduced if proper care is taken during couching and drying process.

Conclusion

The investigation of fiber dimensions in this study has identified giant bluestem, bagasse, maize stalk, peel from maize cob, bahaman grass, gamba grass, pineapple leaf, banana stalk and banana leaf as non wood raw materials feasible for papermaking. The study shows the resourcefulness of wastes in our environment and as alternative use to timber in order to protect and conserve our environment from deforestation with its attended effects.

REFERENCE

Anonymous, (1998). Rages to Riches-India. p 1-8 *http://www.tve.org/ho/doc.cfm?aid=241&lang=English*

Anonymous. (1955). The relationship between the morphological characteristics of the fibres from tropical woods and the quality of pulp and paper obtained from them. Pp. 378 - 380 in *Pulp and Paper Prospects in Latin America.* Regie Industrielle de la Cellulose Coloniale, FAO, Rome.

Biermann, C. J. (1993). Essentials of pulping and papermaking. Academic press, San Diego, CA, USA 472.

Douglas, W.J. (1997). The Praireie Paper Project 1-9pp. *www.prairiepaper.html*

Edward, F.T. (1982). Paper and Papermaking. New Age Encyclopedia (vol.14). Lexocon Publication, INC pp (51-5)

Garboni, G. (2005). Making and Recycling paper at home. Fun Science Gallery. *www.funsci.com*

Kırcı, H., (2006). *Pulping Industry*. KTU Faculty of Forest Press, No: 86,Trabzon

MBendi Profile, (2001). World: pulp and paper Industry-Word pulp and paper.

Pande, H.(1998). Non wood fiber and Global supply. Faculty of Forestry of Toronto, Ontario.

Runkle, R.O.H. (1952). *Pulp from Tropical Woods.* Bundesanstalt fur Forst und Holzwirtschaft, Reinbek Bez. Hamburg: 20 – 25.

Vivek, K. and Macheswari, R.C. (1998). Handmade Papermaking in India: A sustainable Production System. Center for rural development and Technology India institute of Technology, Delhi Hau-Khas, New Delhi-11016.

Weston, L. (1996). Tree-Free Paper. The alternatives are getting better.