International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 02 Issue: 04 | July-2015 www.irjet.net p-ISSN: 2395-0072

Pulp and Paper Production from Nigerian Pineapple Leaves and Corn Straw as Substitute to Wood Source

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Abstract: *Wood contributes majorly as raw material in conventional pulp and paper production worldwide, whereas the depleting forest resources to obtain wood had made a significant impact on the environment and human. This has made the search for alternative fibre in non-wood materials imperative in pulp and paper production. Nigeria has abundance of agro waste materials like pineapple leaves and corn straw that have not been fully utilized. Therefore, this study aims at investigating the suitability of pineapple leaves and corn straw in pulp and papermaking. Pulping of pineapple leaf and corn straw was achieved through chemical pulping method (Soda pulping) and the pulp obtained were tested for their chemical compositions; Lignin content (11.5%, 6.23%), Ash content (1.2%, 14.9%), Pulp yield (15%, 18.05%), Cellulose content (65%, 45.12%) for pineapple leaves and corn straw pulps respectively. The resulting pulp was used for paper making and the papers obtained were tested for their mechanical properties; Grammage (45.62, 74.01) g/m², Thickness (0.24, 0.42) mm, Tensile index (0.19, 5.03) Nm/g, Tear index (17.19, 12.29) Nm²/g, Modulus of Elasticity (5.87, 0.13) N/mm² and Elongation at break (1.14, 1.08) mm, for papers made from pineapple and corn straw pulps respectively. The surface morphology of the papers produced were analysed using Scanning Electron Microscopy. The result of Scanning Electron Microscopy (SEM) analysis of the papers showed that there is a condensed and packed arrangement of fibres in both pineapple leaves and corn straw. The overall results showed that Nigerian pineapple leaves and corn straw has a promising potential as alternatives fibres for pulp and paper making industry.*

Keywords: Pineapple leaves, Corn straw, Tensile strength, Tear index, Thickness.

1. INTRODUCTION

Wood contributes to about 90% of the conventional raw material used for pulp and paper production in the world [1]. However, depletion of forest resources to obtain wood had made an impact on the environment and human [2]. Several agricultural food crop residues including rice husk, corn straw, okra stalks, corn stalk, plantain stalk, pineapple leaf and corn husks which do not have immediate beneficial applications in many communities have been proposed to be potential sources of pulp [3]. Nigeria has abundance of agro waste material that have not been fully utilised to maximum production. Examples of such agro waste materials are pineapple leaf and corn straw. Pineapple (Ananas comosus) is the common tropical plant which consists of coalesced berries. It consists of cellulose, holocelluloses, hemicelluloses and lignin along with some extractives such as gum and resin. Previous researches indicate that pineapple leaf from different cultivar contained higher cellulose content than wood fibre. Such findings suggest that non-wood species can provide a good solution to the need for alternative fibre. Corn, introduced into Africa by the Portuguese in the 16th century is a major source of starch and has become Africa's most important staple food crop. Cornstarch (maize flour) is a major

ingredient in home cooking and in many industrialized food products. Corn Stover consists of the leaves and stalks of maize plants left in a field after harvest. It can be grazed as forage or collected for use as fodder but is commonly not fully utilized. It can also be used as a fuel for bioenergy or as feedstock for bioproduct synthesis.

Non-wood plants offer several advantages including short growth cycles, moderate irrigation and fertilization requirements and low lignin content to alleviate energy and chemicals used during pulping [4]. There is an abundance of non-wood fibers potentially available for the paper industry. Since all these plant materials contain cellulose in form of fibres, they stand to be potential sources for pulp with lesser environmental degradation threat than wood which is traditionally the most widely used ligno-cellulosic material in the production of pulp, furniture and boards of diverse types, as well as being a source of energy [5]. Thus the use of pineapple leaf and corn straw for pulp and paper production is investigated in this study.

2. Materials and methods

2.1 Materials

Fresh samples of pineapple leaves were obtained from the crown of freshly harvested pineapple fruits from various local pineapple processing stations around Ogbomoso while corn straw was obtained from Araada market and Aguodo farm in Ogbomoso, Oyo State respectively.

(a) (b) (c)

Fig.1: Sample of (a) Fresh Pineapple Crown (b) Pineapple leaves removed from the crown (c) Chipped Pineapple leaves

Fig.2: (a) Sample of dried corn straw (b) Sample of chipped corn straw

2.1.1 Sample Preparation:

The collected sample each was air-dried in the laboratory and thereafter chipped into small sizes using cutting tools, such as knife and scissors. Moisture content of the samples was determined using the moisture analyser. Part of the dried samples was grinded and size selection was done using a sieve of mesh size 0.4 mm. The grounded samples each was stored for further analysis.

Chemical composition analysis of pineapple leaves and corn straw:

Chemical composition (Lignin, Ash, Cellulose contents and Pulp yield) of pineapple leaves and corn straw was determined according to Tappi Standard Test Methods [6, 7]. Prior to this determination, the grounded pineapple leaf and corn straw was subjected to ethanolic extraction for about 6 hrs using soxhlet apparatus. This was done to remove the extractives content of the samples which may interfere with the composition determination.

2.1.2 Pulping process

Pulping of chipped pineapple leaves and corn straw was achieved using chemical pulping method (soda pulping). About 200g of the raw material (oven-dry weight) was loaded into a 1000ml conical flask which was then placed in a pressure pot containing sufficient amount of water. 42 g of pulping chemical (caustic soda) was dissolved in 600 ml of water (7% sodium hydroxide) and the solution was poured into the conical flask. The ratio of volume of water to the weight of raw material was 3:1. Pulping time was 180 mins (3hrs).

Fig 3: Unbleached Pulp

2.1.3 Pulp Washing and preparation

The pulp obtained was thoroughly washed under running water to remove the residual chemicals still present and the pulp samples were defiberized in a laboratory steel blender, which act as a wet disintegrator, for 5 mins and the screening was done by sieving through a screen.

2.1.4 Pulp Bleaching

A weighed amount of dried pulp was introduced into a beaker, and measured amount of Hydrogen Peroxide (H_2O_2) was added. The beaker was then heated on a hot plate for about 20mins after which it was observed that the pulp colour had changed to white.

Fig 4: Pulp Bleaching and Bleached pulp

2.1.5 Production of Handmade Paper:

Paper sheets were produced from both bleached and unbleached pulps using a handmade paper mould and deckle. Pulps (fibres) were dispersed inside clean water while the paper mould was used to get the fibres out of the water. The paper mould with the fibres was then air dried for about 3 hours in an oven**.** After drying, the paper samples were then pressed with an electric hot iron to improve the smoothness of the paper.


Fig 5: Blended Fibres spread on a paper former and Air-Drying of paper

2.1.6 Paper Characterization:

Paper characterization was done using a Universal Testometric Machine to determine the grammage, tensile strength, tear index, thickness, modulus of elasticity and elongation at break.

2.1.7 *Surface morphological observation*

The handmade paper sheets from both pineapple leaves and corn straw were observed under Scanning Electron Microscope (SEM) to study its fibre morphogical properties.

3. RESULT AND DISCUSSION

3.1 Results

Table 1: Chemical composition of Pineapple leaves and Corn straw

Agro waste	Pulp yield (%)	Cellulose (%)	Ash content (%)	Lignin content (%)	Moisture content (%)
Pineapple leaf	15	65	1.2	11.5	81.6
Corn straw	18.05	45.12	14.9	6.23	62

The results of the chemical composition analysis of pineapple leaves and corn straw showed that cellulose, which is the major chemical component of fiber wall make up approximately 65% and 45.12% of pineapple leaves and corn straw

respectively. Cellulose is the component that makes the fibre inside non-wood materials stronger. These are important parameters in determining the suitability of a raw material for pulp and papermaking. The quality of fibre produced from non-wood materials depends on the contents of cellulose, hemicellulose, and holocellulose. Higher contents of cellulose can provide stronger fibers, thereby increasing the quality of the paper produced.

The result also shows that pineapple leaf and corn straw contains low lignin of approximately 12% and 7% respectively. Low lignin content has been reported as one of the advantages inherent in the use of non-wood materials for pulp production as lignin functions as adhesive to bind the cellulose fibre together. Also, materials with low lignin contents require relatively small amount of chemical for pulping [8]. Lower lignin content is easier to discard from the pulp, and the paper that will be produced is of greater quality compared to that from other non-wood materials.

Pineapple leaf was found to have lower ash content (1.2%) than corn straw (14.9%). The function of ash content is to show the absence or presence of other materials slightly or in combination. This shows that corn straw has a higher presence of other materials which are various chemical, metallic and mineral matters. The low ash content indicates that pineapple leaf pulp has the potential to produce good quality paper. Pineapple leaf has very high moisture content (81.6%) compared to corn straw. This high moisture content will affect the mechanical and surface properties of the paper produced which indicates a less dimensional stability against the grain. Quality paper needs a very good dimensional stability against the grain because the structure and the strength of the paper depend on it. Cellulose fibre can swell from 15 to 20% from dry condition to saturation where it can cause the change in dimension stability. Such change in dimension will make the dimensional stability decrease cause the undesirable cockling and curling in the dimensional stability of the paper.

Table 2: Result of paper characterization from different noon wood materials

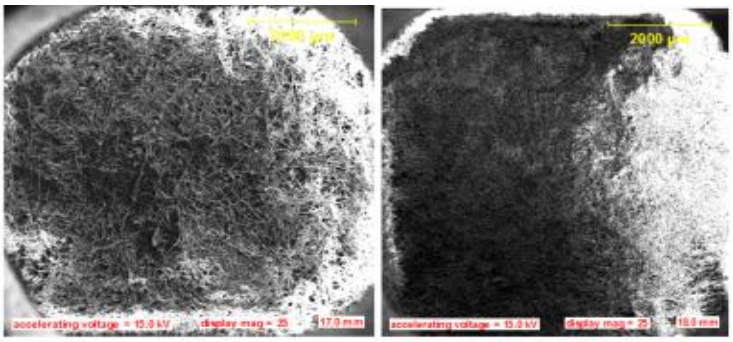
Agro wastes	Grammage	Thickness	Tensile index	Tear index	Modulus of elasticity	Elongation at break
Pineapple leaf	45.62	0.24	0.19	17.19	5.87	1.14
Corn straw	74.01	0.42	5.03	12.29	0.13	1.08

3.2 Paper characterization (Tensile strength of paper sheet)

The mechanical and strength analysis of paper produced reflect the intrinsic chemistry, morphology, and structure of the individual fibres as well as the network structure of the paper [9]. The result of tensile strength analysis done on the paper samples produced from pulp from pineapple leaf and corn straw is presented in Table 2. The result shows that pineapple leaf and corn straw could be considered as a promising raw material for papermaking applications. However, it must be noted that residual lignin, impurities, pulp consistency, degree of pulp beating, relative humidity of the environment are few of the factors that could influence the properties of paper sheets produce from any pulp. The dimensions and strength of the individual fibers, their arrangement, and the extent to which they are bonded to each other are all important factors contributing to test results.

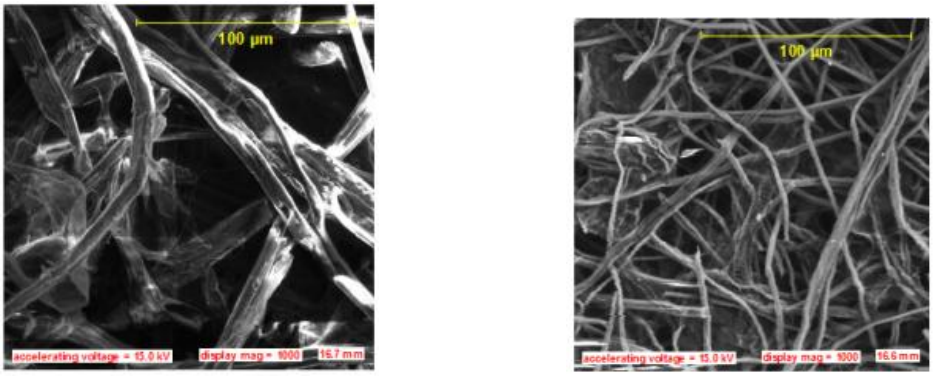
3.3 Surface Morphological Analysis

Scanning electron microscopy (SEM) analyses of pineapple leaf and corn straw papers are shown below. The SEM analysis reveals the microscopic structure of the material. As shown in Fig. 6 and 7, it was observed that the higher the magnification the clearer the fibre structure and the lower the magnification the smoother the coverage. It was observed from the SEM images below that pineapple leaf had the smoothest coverage and a clearer fibre structure which makes pineapple leaf pulp a best substitute to wood in pulp and paper production.



(a) Corn straw (b) Pineapple leaf

Fig 6: SEM images of paper from different non wood materials with smaller magnification (x25)



(a) Corn straw (b) Pineapple leaf

Fig 7: SEM images of paper from different non wood materials with larger magnification (x1000)

4. Conclusions

The results obtained from this study have shown that pineapple leaf and corn straw are suitable non wood raw materials for papermaking. The study shows the suitability of agro wastes materials in our environment as alternative to wood source for pulp and paper making in order to protect and conserve our environment from deforestation with its attendant effects. The study also shows pineapple as a highly potential substitute in paper production because of its high content of cellulose and low lignin content compared to corn straw.

ACKNOWLEDGEMENT

The authors are grateful to the entire staff of Federal Institute of Industrial Research Oshodi (FIIRO), Lagos, Nigeria for giving them opportunity to make use of the analytical equipments of the establishment.

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BIOGRAPHIES

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