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# Utilization of Pineapple Crowns (Wastes) for Sustainable Paper Production: Climate Change Mitigation and Wastes to Wealth Approach

MOJIBAYO IKUSEDUN[1], ADEWOLE AYOBAMI ADERINLEWO[2], Olayemi Johnson ADEOSUN[3], SAHEED BABATUNDE BADA[4], ADEBISI ASHAWE-ESAN[5]

*[1]Chemical, Fibre and Environmental Technology Department, Federal Institute of Industrial Research Oshodi, Lagos, Nigeria.*

*[2]Agricultural and Bioresources Engineering Department, Federal University of Agriculture Abeokuta, Nigeria.*

*[3]Agricultural and Bioresources Engineering Department, Federal University of Agriculture Abeokuta, Nigeria.*

*[4]Environmental Management and Toxicology Department, Federal University of Agriculture Abeokuta, Nigeria.*

*[5]Livestock Science and Sustainable Environment (CEADESE). Federal University of Agriculture Abeokuta, Nigeria.*

*Corresponding Author: Ikusedun Mojibayo*

***Abstract*** ***-The paper industry currently depends on forest trees as fibre sources for paper production, contributing to deforestation which destroys ecosystems that are vital to wildlife and humans alike. Deforestation represents a growing threat to all lives on earth, driving dangerous carbon emissions and exacerbating the climate crisis. Like the oceans, forests absorb excess atmospheric carbon dioxide, serving as a much-needed buffer against irreversible climate change. In a bid to address deforestation caused by the paper industry, this study investigated the potentials and suitability of pineapple crowns (wastes) as fibre sources for sustainable paper production. The pineapple crowns were de-fiberized and fibre dimensions were examined. Fibre length, fibre diameter, lumen width and cell wall thickness were found to be 2.54 mm, 35.19 µm, 36.67 µm and 5.75 µm respectively. Pulping was done through soda pulping method, papers were produced with the resulting pulps, the papers exhibited different tensile strength values ranging from 188.667 N/m$^2$ to 248.667 N/m$^2$, elongation @ break and force @ Peak(N) of papers were found to have different values. The chemical components, fibre dimensions, and tensile properties exhibited, all show that pineapple crowns have great potentials for paper production.***

***Index Terms: Pineapple, Fibres, Dimensions, Paper, And Environment***

## I. INTRODUCTION

The world population is increasing with increase in demand for papers. As the paper industry is expanding globally on a daily basis; paper applications are steadily increasing, and has exceeded 400 million tons per year according to The Environmental Paper Network (TEPN 2018).The expansion of the paper industry has been a thing of great concern from an environmental perspective due to the over reliance of the pulp and paper industry on wood fibres as raw materials. The paper industry raises environmental concerns on multiple fronts from deforestation to climate change, loss of biodiversity and soil erosion to various degrees of health issues (Ayoade 2023). Paper production absorbs a substantial and increasing portion of the global wood harvest. In 1983, roughly 35 percent of the commercial wood harvest worldwide was used in the production of paper products, and this is projected to grow to 70 percent by the year 2030. The global production of paper and cardboard stood at approximately 419.7 million metric tons in 2017. More than half of that production was attributable to packaging papers, while almost one third was attributable to graphic and writing papers. Currently, pulp and paper products consume 50 % of harvested timbers in the United States. The paper industry is facing environmental pressure on multiple dimensions, especially in light of global concerns over CO2 emissions, deforestation and climate change. Paper is one of the most obvious culprits of deforestation—after all, paper is made from trees. In 2019, the US paper industry produced 78 million tons of paper and cardboard. Making one ton of paper requires 24 trees. The paper industry routinely destroys forests to make way for papers (Fagbemi, 2014), hence the need to look for non-wood fibre sources that can give quality pulp for paper production.

## II. MATERIALS AND METHODS

### 2.1 Determination of fibre dimensions of pineapple crowns.

The experiment was carried out following the approach employed by Jorge (2000) to keep error below 5 % for a 95 % confidence level. Pineapple crowns were collected, dried and cut into strands of 1 cm x 2mm x 2mm each of the pineapple crowns. The strands were put in a test tube. The test tube containing the strands of pineapple crown leaves was filled with the solution of acetic acid and hydrogen peroxide ratio 1:2 (v/v). i. e. 75 ml of acetic acid and 150 ml of hydrogen peroxide. The test tube was put in a water bath; the water bath was heated to boiling point for 2hrs. The bombardment of the water molecules in the water bath and the action of the solution of acetic acid–hydrogen peroxide caused the fibres to bleach to become white and disintegrated into slivers of fibres (loose, slender fragments), the process which is termed maceration. The test tube was agitated to aid further disintegration of the fibres into slivers.

After hot maceration, the slivers were washed by decanting the acetic acid–hydrogen peroxide solution in the test tube and replaced it with water in the test tube, it was done three times to ensure thorough washing of the slivers. The washed slivers were poured into petri dishes, stained with fushsin stain (violet blue) and then examined under a micrometer mounted on an Olympus light microscope (Standard 25) and as a result, smooth and easy microscopic examination of the slivers was achieved. The microscopic examination of examined ten slivers showed the fibre dimensions such as fibre length (FL), fibre diameter (FD), lumen width (LW) and cell wall thickness (CW) of the slivers (Table 1).

Table 1: Fibre Dimensions of Pineapple Crowns

| Parameter | Test Samples | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean | |
| F L (mm) | 3.02 | 2.91 | 3.02 | 2.26 | 2.64 | 2.26 | 2.01 | 2.39 | 2.64 | 2.25 | 2.54 | s |
| F D (µm) | 26.30 | 16.42 | 57.96 | 75.60 | 64.26 | 15.04 | 11.34 | 37.56 | 10.08 | 37.30 | 35.19 | |
| LW (µm) | 42.52 | 12.52 | 43.78 | 52.52 | 43.90 | 22.64 | 22.52 | 13.78 | 42.52 | 13.78 | 31.05 | |
| CWT (µm) | 1.53 | 1.58 | 21.93 | 29.58 | 24.42 | 0.96 | 3.57 | 1.53 | 3.06 | 1.42 | 8.96 | |

### 2.2 Paper Making Process

#### 2.2.1 Soda pulping of pineapple crowns

Pulping of pineapple crowns was done through soda pulping method with sodium hydroxide, the pineapple crowns were washed with clean water and sorted to remove unwanted substances such as sand and stones. They were dried under natural conditions for 2 weeks. The dried corn sheaths and pineapple crowns were chipped into smaller sizes of about 12-25 mm with cutting tools such as knives, scissors, after which they were pulped. A 1 kg of pineapple crowns was weighed and poured into a vertical rotary digesters, Model Y2-712- 4 | Standard JB | T II 07 – 2013, 5000 mL of water was also weighed into the vertical rotary digester (reactor) in ratio 1:5 solid to liquid (pineapple crowns: water) for all the processes, two batches of five experiments (Tables 2 and 3). In the first batch of pulping of pineapple crowns, the concentration of sodium hydroxide (NaOH) in the pulping process was varied from 10 to 30% i.e. 10, 15, 20, 25 and 30% while temperature at 160°C and time 60 min were kept constant for all the processes. In the second batch of the pulping processes, only temperature was varied from 120 to 160$^0$C i.e. 120, 130, 140, 150 and 160$^0$C. Sodium hydroxide concentration and pulping time were both kept constant at 10% and 60 min, respectively for the pulping processes.

As the digester rotated, there was agitation in the digester, heat from the digester made it possible for easy penetration of the pulping chemical (sodium hydroxide) into the pineapple crowns and helped to cause delignification of pineapple crowns, breaking down and separating lignin from cellulose fibres. As the temperature of digester increased, pressure also increased which also contributed to quick delignification. The reason for varying pulping conditions— sodium hydroxide concentration and temperature throughout the experiments was to determine the effects of pulping conditions on papers produced from pineapple crowns. At the end of each pulping process, the digester was turned off and allowed to cool. The mixture of pulp (delignified fibres) and residual liquor (spent liquor) was collected with a 50-L bucket and separated by filtration; pulp was thoroughly washed with distilled water to separate pulp from the lignin containing black liquor. Washing of pulp was thoroughly and continuously done until the water coming out from the pulp became colouless and was no longer soapy, water was subsequently quizzed out of the resulting pulp which was air dried for 72 hrs.

Table 2: Pulping Conditions for Pineapple Crown (Batch 1 Experiments 1-5)

| | Conc NaOH (%) | Temp ( $^{O}$C) | Time (Min) | Pressure (Bar) |
|---|---|---|---|---|
| 1. | 10 | 160 | 60 | 0.60 |
| 2. | 15 | 160 | 60 | 0.65 |
| 3. | 20 | 160 | 60 | 0.60 |
| 4. | 25 | 160 | 60 | 0.60 |
| 5. | 30 | 160 | 60 | 0.60 |

Table 3: Pulping Conditions for Pineapple Crown. Batch 2 Experiments 1-5

| | Conc NaOH (%) | Temp ( $^{O}$C) | Time (Min) | Pressure (Bar) |
|---|---|---|---|---|
| 1. | 10 | 120 | 60 | 0.20 |
| 2, | 10 | 130 | 60 | 0.25 |
| 3. | 10 | 140 | 60 | 0.30 |
| 4. | 10 | 150 | 60 | 0.35 |
| 5. | 10 | 160 | 60 | 0.40 |

### 2.2.2 Pulp Refining and Paper Forming

A mass of 25g of unbleached pineapple crown pulp was mixed with 500ml of water to form a mixture. The mixture of pulp and water was gently blended with a laboratory blender (Model No. ES - 1008) for about 10 min to form slurry. The resulting slurry from the blended mixture was poured into a handmade sheet former (A4 size deckle and mold) with netted sieve (400 - mesh). The sheet former was partially immersed below the water level, the slurry consisting of separated and loose cellulose fibres in water was agitated to disperse completely, the sheet former was raised up for water to drain through the screens of the sieve and consequently, a mat of randomly interwoven fibres was formed on the mold. The mold and the formed mat of randomly interwoven fibres were air dried; the mat was removed as paper after drying.

## III. EFFECTS OF PULPING CONDITIONS (CONCENTRATION, TEMPERATURE AND TIME) ON TENSILE STRENGTH OF PAPERS PRODUCED FROM PINEAPPLE CROWNS

Tensile tests were carried out on all the paper samples produced according to testometric testing methsod with a testometric material testing machine (Model No: BS903, M500-25KN, OL11 INR, Roshdale) at test a speed of 100.000 mm/min. The papers were cut into stripes and loaded through the clamps of the machine. Test specimens geometry was sample width: 25.000 mm, sample length: 100.000 mm and sample grammage: 60.000 g/m². The tensile strength of papers produced from pineapple crown papers are presented in Tables 4 and 5. Table 4 presents the pulping conditions with sodium hydroxide concentration varied from (10- 30 %) at constant temperature of 160$^{O}$C and time 60 min. Results show that the lowest sodium hydroxide concentration of 10 %, at constant temperature 160$^{O}$C and time 60 min, exhibited the lowest tensile strenght of 203.33 N/mm$^{2}$, the highest elongation of 30.431mm while force was found to be 10.400N. Results in Table 4 shows that as pulping chemical concentration was increasing from 10 – 30%, the tensile tensile strength of papers also increased from 223.333 – 257.667 N/mm$^2$, this indicated downward reduction in lignin content of the pulps from which the papers were produced (Malachowska *et al*, 2020).

Table 5 presents the tensile properties of the papers produced from pineapple crowns when only temperature was varied from 120 to 160$^O$C while time and sodium hydroxide concentration were both kept constant at 60 min and 10% respectively. Results obtained show that as pulping temperature increased from 120 – 160 $^O$C keeping the two other variables - concentration and time constant, the tensile strength of papers also increased from 208.333-255.667 N/mm$^2$, an indication of downward reduction in lignin content of the pulps from which the papers were produced. This study reveals that the tensile strength of the papers increased due to increase in lignin removal caused by higher concentration of the pulping chemical, higher pulping temperature and longer pulping time. The results are in accordance with what was demonstrated by Malachowska *et al*. (2020). To produce high quality papers, results show that the removal of lignin is necessary because the presence of lignin weakens the strength of fibre and causes yellowing in papers particularly, news prints. Lignin free pulps give papers with high tensile strength, the more lignin is removed (delignification), and the higher the tensile strength of the paper produced.

Table 4: Effect of Sodium Hydroxide Concentration on Tensile Properties of Pineapple Crown Papers

| | Elongation@ Break (mm) | Force (N) | Final Strain (mm) | Tensile Strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 18.148 | 7.200 | 18.148 | 223.333 |
| 2. | 14.406 | 61.800 | 14.406 | 235.333 |
| 3. | 12.592 | 64.500 | 12.592 | 241.333 |
| 4. | 7.783 | 64.600 | 7.783 | 253.667 |
| 5. | 6.187 | 74.900 | 6.187 | 257.667 |

Experiment 1-5: NaOH concentration varied from 10 % - 30 %, temperature 160 $^O$C and time 60 min remained constant

Table 5: Effect of Temperature on Tensile Properties of Pineapple Crown Papers

| | Elongation@ Break (mm) | Force (N) | Final Strain (mm) | Tensile Strength (N/mm$^2$) |
|---|---|---|---|---|
| 1. | 16.045 | 9.500 | 16.045 | 208.333 |
| 2. | 12.625 | 18.300 | 12.625 | 213.333 |
| 3. | 10.024 | 41.500 | 10.024 | 236.333 |
| 4. | 8.043 | 46.900 | 8.043 | 255.667 |
| 5. | 7.851 | 49.300 | 7.851 | 267.667 |

Experiment 1-5: Temperature varied from 120 - 160 $^O$C, NaOH concentration and time were kept constant at 10 % and 60 min respecrively

## IV. RESULTS AND DISCUSSION

The results obtained as shown in Table 1 reveal that pineapple crown fibres exhibited good potentials and are suitable for pulp and paper production. Table 1 shows pineapple crown fibres exhibited fibre length, fibre diameter, lumen width and cell wall thickness of 2.54 mm , 35.19 µm, 36.67 µm and 5.75 µm respectively, the values which conform with TAPPI standard values and are desirable for quality pulp for quality paper production. Pineapple crowns exhibited long fobre Length of 2.54mm, the size considered desirable for quality paper production. Results obtained show that as pulping temperature increased from 120 – 160 $^O$C keeping the two other variables - concentration and time constant, the tensile strength of papers also increased from 208.333-255.667 N/mm$^2$, an indication of downward reduction in lignin content of the pulps from which the papers were produced. This study also revealed that the tensile strength of the papers increased due to increase in lignin removal caused by higher concentration of the pulping chemical, higher pulping temperature and longer pulping time. It also shows that pineapple crowns can be better alternative fibre sources to wood fibres predominantly used in paper production.

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## V. CONCLUSIONS

The study revealed that pineapple crown fibres showed good potentials and are suitable for pulp and paper production as they exhibited fibre characteristics desirable for pulp and paper production. Pineapple crowns exhibited fibre length of 2. 54 mm, fibre diameter 35.19 µm, lumen width 31.05 µm and cell wall thickness of 8.96 µm. Pineapple crowns are good sources of long fibre (2. 54 mm) as found in soft woods. Results also that processing conditions have effects on tensile strength of papers produced. Concentration of the pulping chemical (NaOH) as low as 10 % gave quality paper at 160°C for 60 min. Concentration of the pulping chemical (NaOH) as high as 30 % gave higher quality paper at 160°C for 60 min. The higher the concentration of the pulping chemical (NaOH), the higher the tensile strength, the higher the quality of papers produced at 160°C and 60 min. The higher the pulping temperature, the lower the pulp yield but higher tensile strength and higher quality papers produced. The research contribute to the development of a sustainable and eco-friendly paper production processes, while also promoting the utilization of agricultural residues for paper production, reducing wastes, finding alternative fibre sources to forest trees, reducing deforestation and carbon emissions, mitigating climate change. and converting wastes to wealth.

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