

Characterisation and Evaluation of Bast and Core Fibre of Sugarcane (*Saccharum Officinarum*) Bagasse for Pulp and Paper Production

¹Ayorinde Grace.Oluwadunni., ^{1,2*}Odujibe Fausat Olubusola., ¹Bawa-Allah Babajide Nurudeen., ¹Akintade Oluwadurotimi Olutosin. and ³Aina Kehinde S.

¹Department of Chemical Sciences, Faculty of Applied Sciences, KolaDaisi University, Ibadan, Nigeria.

²Department of Chemical Sciences, Lagos State University of Science and Technology, Ikorodu, Lagos. Nigeria.

³Department of Forest Products Development and Utilization, Forestry Research Institute of Nigeria, P.M.B 5054, Jericho hill, Ibadan, Nigeria

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Abstract: This study was conducted to determine the suitability of bast and core fibre derived from *S. Officinarum* bagasse (an agricultural waste) for pulp and paper making. The bagasse was chipped and macerated in a 1:1 mixture of acetic acid and hydrogen peroxide for three weeks to release the fibres. The fibre dimensions were measured under the microscope and morphological indices calculated. Physicochemical properties (ash and moisture content, cold water, hot water and 1 % NaOH solubility) were also determined using American Society for Testing and Materials (ASTM) method. The bast fibre was digested with 2 and 4 M NaOH in ratios 1:10, 1:20 and 1:30 (w/v) at pulp time of 30, 60 and 90 minutes, respectively. The mean values obtained for fibre length, fibre diameter, lumen width and cell wall thickness for both core and bast fibre were in the range 0.736 mm to 1.542 mm, 0.0237 mm to 0.0242 mm, 0.0178 mm, and 0.0025 mm to 0.0029 mm respectively. The morphological indices for core and bast fibres were; 10.54 to 12.58, 0.35 to 5.81, 32.21 to 67.43 and 78.83 to 78.90 for coefficient rigidity, runkel ratio, felting power, and coefficient flexibility respectively. It was observed that the best pulp yield was obtained with 1:10 (w/v) solid to liquid ratio of 2 M NaOH solution at digestion time of 90 minutes. The papers produced were examined using Scanning Electronic Microscope (SEM). The finding of this study revealed that bast fibre of *S. Officinarum* plant holds greater promise as a sustainable alternative source for papermaking than the core fibre.

Keywords: Sugarcane Bagasse, Bast Fibre, Core Fibre, Pulp yield, Paper

I. Introduction

The pulp and paper industry is one of the biggest industries in the world, due to the high usefulness of paper in communication and study, the production of papers has increased internationally and is still expected to expand in the nearest future [13]. Likewise, as a result of increase in birth rates and societal interest in education, paper technology is progressing because electronic study methods cannot eradicate the usage of paper in education [18]. Paper is used for paperwork in offices and for packaging in businesses, demonstrating its extensive applications, necessity, and enormous relevance in both developed and developing nations like Nigeria [20]. According to [11], the importance of pulp and paper products in modern civilization's rise in literacy cannot be overstated. These needs for paper have made ongoing study into the pulping and paper-making processes necessary. As wood is regarded as the primary raw material for producing paper and wood-based panel products, the high demand for wood consumption has a negative influence on the ecosystem, harms the environment, and increases greenhouse gas emissions. This issue motivated researchers to look for additional raw materials other than wood for the production of paper. Through extensive investigation, various non-wooden plants for creating paper have been identified, including hibiscus plants, sisal, and kanef. Furthermore, it has been demonstrated that a variety of agricultural wastes, including rice straw, wheat straw, cotton linters, corn stalks, and sugarcane bagasse, have the potential to be used in the production of paper. Since sugarcane bagasse possesses long fibres, it is regarded as the most highly recommended agricultural raw material for pulp production [2, 3, 12]. Using bagasse as a source of fiber for paper manufacture is more environmentally friendly and sustainable than cutting down trees, which can result in deforestation and biodiversity loss. Sugarcane is comparatively renewable because it can be grown in 6–12 months as opposed to years like trees do.

Bagasse is the fibrous by product produced from sugar cane after the juice has been removed. Sugarcane (*S. officinarum*) is a perennial grass [15], in comparison to other crop leftovers like wheat and rice straw, bagasse has a number of advantages. Bagasse can be used to make paper in addition to serving as a raw material for the production of sugar. However, due to a lack of knowledge, most sugar factories burn their waste instead of converting it into new applications. Another way to manage trash and reduce environmental contamination is to continue using bagasse to make paper.

In addition to being a fibrous plant, bagasse needs to have its internal structure and various elements well examined in order to provide enough knowledge about their impact on the types and quality of paper that may be created with them. Therefore, the

purpose of this study was to examine the fiber properties, morphological indices and pulp yield of sugarcane bagasse for paper making.

II. Materials and Methods

Sample Collection and Preparation

Twenty-five (25) pieces of sugarcane (*S. officinarum*) samples were collected from a local market in the Akinyele Local Government Area of Ibadan, Oyo State, Nigeria (Plate 1). Following the extraction of sugarcane juice from the raw sugarcane, bagasse was collected from each sample.

The extracts were later washed with distilled water to eliminate any residual sugar, oven dried at 100°C until constant weight was observed. The dried bagasse samples were subsequently separated into bast and core by hand picking (Plate 2 and plate 3 respectively).



Plate 1: Raw Sugarcane



Plate 2: Bast Bagasse fibre



Plate 3: Core Bagasse fibre

Microscopic features of the fibres

The bast and core fibres were separated, sliced into fine threads, and allowed to soak for three weeks in beakers filled with a 1:1 solution of glacial acetic acid and 59% hydrogen peroxide [1]. To liberate the fibres, a magnetic stirrer was used to agitate the beakers periodically. Following maceration, the fibres were stained with aqueous safranin and placed on glass slides using 20% glycerol for light microscope viewing [7]. A stage micrometer with the following magnifications was used to measure the fibre dimensions of each sample portion of the bast and core fibre: 10X for the fibre length, 4X for the fibre wall thickness, and 4X for the fibre lumen width. The morphological indices were calculated in accordance with [14] as follows;

1. Felting power (slenderness) = Fibre length / Fibre diameter
2. Elasticity coefficient (%) = (lumen width / fibre diameter) x 100
3. Rigidity coefficient (%) = (Cell wall thickness / fibre diameter) x 100
4. Runkel ratio = (2 x Cell wall thickness) / Lumen diameter
5. Felting flexibility = (Fibre length / Cell wall thickness) x 100

Determination of Physiochemical properties

Moisture Content

This was done in accordance with [27]. Empty covered crucibles were heated in a muffle furnace at 600 °C, then allowed to cool in a desiccator and weighed to the nearest 0.1 mg. 2g sample was added to each crucible, which were subsequently placed in the drying oven at a temperature of 100-105 °C with the covers removed. After 1 hour, the crucibles were taken out, cooled in a desiccator, and weighed until a constant weight was achieved, measured to the nearest 0.1 mg. The percentage of moisture was determined based on the weight of the air-dried sample, using the following calculation:

$$\text{Moisture percent} = \frac{W_1 - W_2}{W_1} \times 100$$

Where: W_1 = Weight of the air dry sample and the crucible (g),

W_2 = Weight of the oven-dry sample and the crucible (g)

Ash content: This was done in accordance with [27]. The ash content was analyzed by taking 2 g of each moisture-free sample and placing it in a crucible after removing its cover. This crucible was then positioned in a muffle furnace and heated until all carbon was burned off. The test samples were gradually heated to prevent flare-ups and to safeguard the crucible from significant cracking. The final ignition temperature was set between 580 and 600 °C; the crucible with its contents were stored in a desiccator, and the cover was loosely replaced, then allowed to cool and weighed accurately. Heating was continued in 30-minute intervals until the weight was stable within 0.1 mg after cooling. The percentage of ash content for each sample was calculated using the weight of the moisture-free sample, as shown in the equation below:

$$\text{Ash percent} = \frac{W_1 - W_2}{W_1} \times 100$$

Where; W_2 = Weight of Ash (g), W_1 = Weight of oven-dry sample (g)

Determination of water solubility

Water solubility was determined in accordance with [27]. The methods adopted for water solubility determination are cold water solubility and hot water solubility.

Cold water solubility: A 2 g portion of each sample, whose moisture content had already been established, was placed into a 400 ml beaker and covered with 300 ml of distilled water. The mixture was digested at a temperature ranging from 23 to 25 °C, with regular stirring for a duration of 48 hours. The material was then filtered through a fritted-glass crucible using suction and was washed with distilled water. The material was dried to a consistent weight at a temperature between 100 and 105 °C for about 4 hours, then cooled in a desiccator and weighed. The measurement obtained was utilized to calculate the cold water solubility for each sample according to the formula stated below.:

$$\text{Cold water solubility percent} = \frac{W_1 - W_2}{W_1} \times 100$$

Where: W_1 = Weight of moisture - free sample (g) and W_2 = Weight of dried sample after extraction with cold water (g)

Hot water solubility: A 2g portion of each test sample, after determining its moisture content, was placed in an Erlenmeyer flask, followed by the addition of 100 ml of distilled water, and connected to the reflux condenser. The flask was then positioned in a boiling water bath, ensuring that the solution within the flask was slightly below the water level in the bath, and heated gently for a duration of 3 hours. The contents of the flask were filtered through a fritted-glass crucible using suction with hot water, and then dried to a constant weight at a temperature range of 100 to 105°C for about 4 hours. Once dried, the sample was transferred to a desiccator to cool before being weighed. The collected weight was utilized to calculate the hot water solubility for each sample using the formula provided below;

$$\text{Hot water solubility percent} = \frac{W_1 - W_2}{W_1} \times 100$$

Where: W_1 = Weight of moisture - free sample (g) and W_2 = Weight of dried sample after extraction with hot water (g)

One percent Caustic Soda (1% NaOH) solubility determination

This was done in accordance with [27]. A total of 2 g of each test sample was placed into a 200 ml beaker, and then 100 ml of a 1% NaOH solution was added to each beaker. The mixture in the beakers was stirred and then placed in a boiling water bath for one hour. After one hour, the mixture was filtered; the sawdust residue was thoroughly rinsed with 100 ml of hot water followed by 500 ml of a 10% acetic acid solution. The residue was then dried until it reached a constant weight. The data obtained was used to calculate caustic soda solubility using the formula stated below;

$$\text{Caustic Soda Solubility} = \frac{W_1 - W_2}{W_1} \times 100$$

Where: W_1 = Weight of moisture - free sample and W_2 = Weight of dried sample after caustic soda extraction.

Pulping Process

The Pulp Yield (PY) were determined using Technical Association of Pulp and Paper Industry (TAPPI) estimation method [28]. A total of 5g of each type of bast fibre was placed in three stainless steel cups, each containing 50 ml of 2M NaOH. These cups were then placed inside a digester (Anchor 10 L pressure cooker) filled with 3 L of distilled water and heated to a temperature exceeding 120°C for 30 minutes. The bagasse underwent cooking in the digester to separate the fibers by dissolving the lignin present in the material. This procedure was repeated using 100 ml and 150 ml of 2M NaOH for 60 and 90-minute durations, respectively. The experiment was conducted with 50 ml, 100 ml, and 150 ml of 4M NaOH for 30, 60, and 90 minutes, respectively. After completing the digestion process, the residual NaOH and dissolved lignin were washed out from the fibers as illustrated in Plate 4.



Plate 4: Pulped bagasse bast fibre

Paper production

Some of the pulped bast fibre shown in Plate 4 were mixed with water to create a smooth paste. Following this, approximately 500 ml of the blended pulped fiber was placed into a container and bleached from brown to white overnight using 20 mL of ClO_2 along with a H_2O_2 and NaOH solution. The bleach was thoroughly rinsed off with water multiple times and then filtered using a hand-made square sieve to create a filter mat on the sieve. The fiber suspension was poured onto a single-layer sieve, allowing water to drain through the created mat, which was then dried to produce the final sheet of paper.

III. Results and Discussion

Fibre dimensions

The values obtained for fibre dimensions are presented in Table 1 and illustrated in Figure 1a & 1b. The mean values ($n=25$) obtained for fibre length, fibre diameter, lumen width and cell wall thickness for both core and bast fibre of *S. officinarum* were found to be 0.76 mm and 1.54 mm, 23.7 μm and 24.2 μm , 17.8 μm and 18.7 μm and 2.5 μm and 2.9 μm respectively. As observed in Figure 1a, the fibre length of the bast was higher than the fibre length of the core. The values obtained for bast fibre agreed with [25] who reported that longer fibre length is preferred in the production of pulp and paper. Hence, due to the higher fibre length obtained for the bast fibre, it is more preferable than the core fibre for the production of pulp for paper making. The values obtained in this study were also similar to the values obtained by [9, 17]. Also, it was observed that the fibre diameter obtained in this study ranges from 23.7 μm to 24.2 μm . As observed, the values obtained is slightly higher than higher than 20.0 μm and 21.0 μm reported by [17] and [9] for sugarcane bagasse respectively. The mean value of lumen width obtained in this study ranged from 17.8 μm to 18.7 μm . Fibres with large lumen and thin walls tend to flatten to ribbons during pulping and papermaking, thereby causing a good contact between the fibres and consequently having good strength characteristics [16]. A larger lumen width results in better pulp beating because of the penetration of liquid into the empty spaces of the fibres. As illustrated in figure 1b, the mean value of fibre wall thickness obtained in this study ranged from 2.5 μm to 2.9 μm . Increase in fibre wall thickness leads to increase in the strength of the fibre [16]. The core fibre had a higher wall thickness than that of the bast fibre. The values obtained in this study were lower than 8.6 μm reported by [24] on *Thaumatococcus danielli* and similar to 2.9 μm observed in *Steculiasetigera* as reported by [19] and 2.5 μm reported for Bamboo by [22]

Plate 5 and 6 below represent the microscopic images of bast and core fibre of the bagasse. From the illustration, the fibre dimensions were measured and it was observed that bast possesses more fibre than the core.



Plate 5: Microscopic images of bast fibre



Plate 6: Microscopic images of core fibre

Table 1: Results of Fibre dimensions for Bast and Core Fibres

Fibre ($n=25$)	Av Fibre Length (μm)	Av Fibre Diameter (μm)	Av Fibre Lumen (μm)	Av Fibre wall thickness (μm)
Bast	1.54	23.6	17.8	2.9
Core	0.76	23.7	18.7	2.5

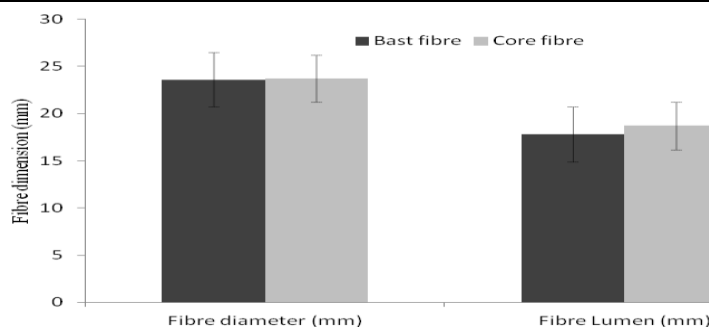


Figure 1a: Fibre diameter and fibre lumen of bast and core fibres

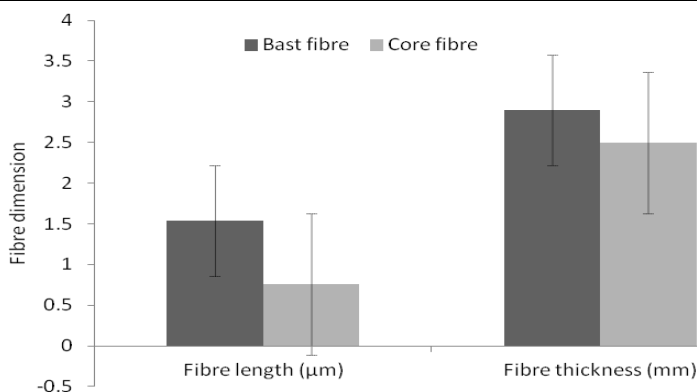


Figure 1b: Fibre wall thickness and Fibre length of bast and core fibres

Morphological Indices

Table 2 and Figure 2a & 2b display the derived indices obtained for the bast and core fibres of *S. Officinarum*. The mean of the felting power was between 67.432 and 32.219, Elastic Coefficient (slenderness ratio) 74.834 and 78.903, while the mean of Rigidity Coefficient was between 12.583 and 10.548. The mean of Runkel Index was between 0.371 and 0.267 while the mean of F. Ratio was between 5.81 and 0.35. From this result of the study, it was observed that the bast fibre gave a higher runkel ratio than the core fibres. The felting had a measurable influence on the pulp yield and the better the paper produced. Report by [4, 26] suggested that if the slenderness ratio is lower than 70, it is not effective for making pulp and paper. The elasticity coefficient of fibre indicates how flexible the material will be in paper production. [24] reported 22% flexibility ratio on *Thaumatococcus daniellii* (Sweet Prayers Plant), [21] reported 22% flexibility ratio on *Abelmoschus esculentus* (okra bark), 21% on *Hibiscus cannabinus* (Kenaf), 20% on *Bombax buonopozense* (Gold coast bombax), [9] reported 63.81% on *Saccharum officinarum*. These indicate that *S. officinarum* had higher flexibility strength compared to those fibres mentioned.

Table 2: Results of Morphological Indices for Bast and Core fibres

Fibre (n=25)	Felting Power	Elasticity Coeff.(%)	Rigidity Coeff.(%)	Runkel Index	Felting Flexibility
Bast	67.43	74.83	12.58	0.37	5.81
Core	32.22	78.90	10.55	0.27	0.31

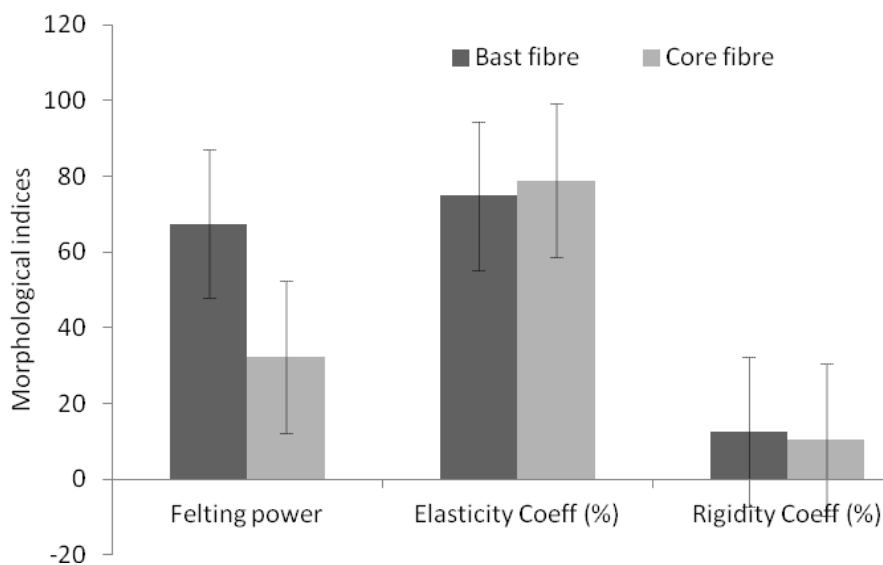


Figure 2a: Felting power, Elasticity coefficient and Rigidity coefficient of bast and core fibres

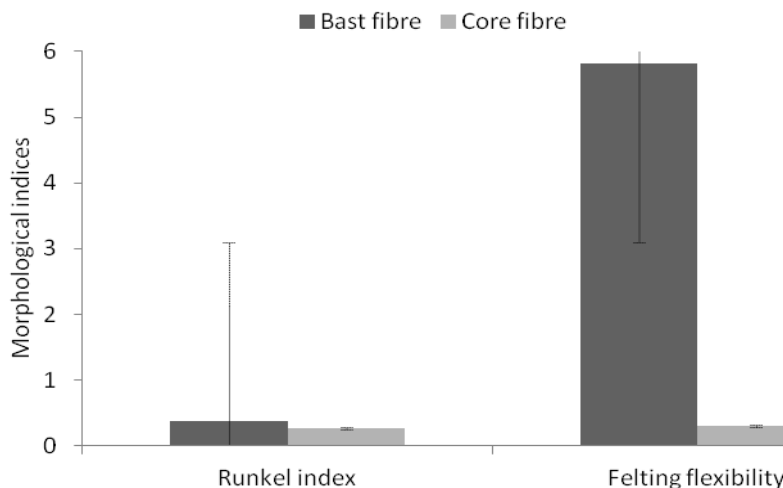


Figure 2b: Runkel ratio and Felting flexibility of bast and core fibres

Physicochemical Properties

Table 3 and Figures 3 & 4 display the average percentage content of the determined physicochemical parameters. The values obtained for physicochemical properties were 14.83 to 15.68 %, 1.50 to 3.00 %, 30.00 to 32.50 %, 36.5 to 38.00 % and 28.5 to 30.5 % for moisture content, ash content, cold water and hot water solubility, 1 % NaOH respectively. The results obtained in this study were higher when compared to the results from previous studies by [6] which had moisture content of 4.5%, ash content of 6.8 % and hot water solubility of 3.12 %.

Table 3: Results of Physiochemical properties of Bast and Core fibres

Fiber	Average moisture Content (%)	Average ash Content (%)	Average cold water solubility (%)	Average hot water solubility (%)	Average one percent caustic soda solubility (%)
BAST	14.83	1.50	32.50	36.50	30.50
CORE	15.68	3.00	30.00	38.00	28.50

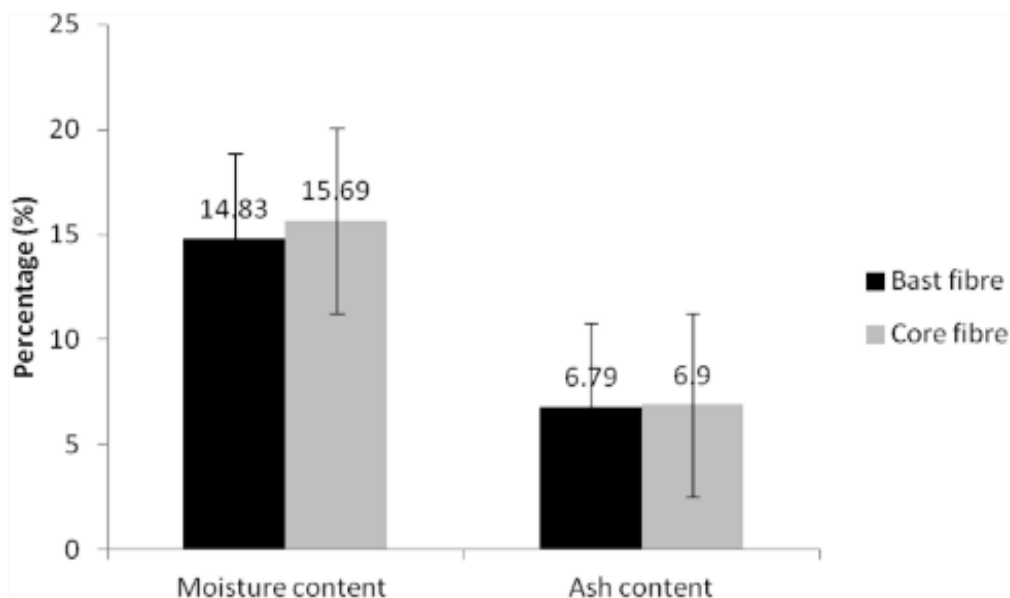


Figure 3: Moisture and ash contents of bast and core fibre

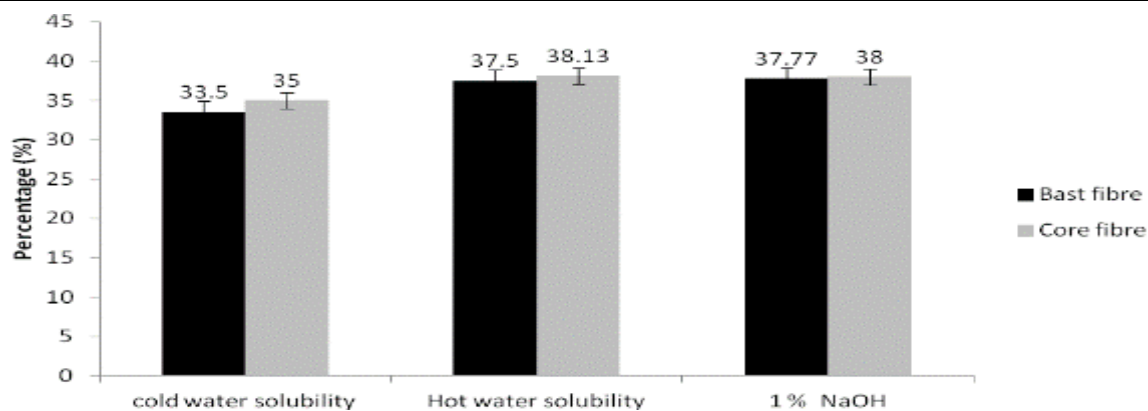


Figure 4: Cold water, hot water and 1% NaOH solubility of bast and core fibres

Pulp Yield

The pulp yield of the bagasse is displayed in tables 4 and 5 utilizing different volumes of 50 cm³, 100 cm³, and 150 cm³ of the 2M and 4M NaOH solution at 30, 60, and 90 minute intervals, respectively. The total pulp yield was found to vary between 31.80% and 50.60 % when using 2M and between 32.40 % and 44.20% when using 4M. According to the pulp yield trend, the lowest pulp yield was achieved with 50 cm³ of 2 M NaOH and a 90-minute digesting period. The grade of the paper produced increases with decreasing pulp production, indicating complete delignification.

Table 4: Results of Pulp yield for 2M NaOH

S/N	Volume of NaOH (ml)	Time (mins)	Average Pulp Yield (g)	Average Pulp Yield (%)
1	50	30	2.06	41.20
2	50	60	1.97	39.40
3	50	90	1.59	31.80
4	100	30	2.53	50.60
5	100	60	2.10	42.00
6	100	90	1.72	34.40
7	150	30	2.45	49.00
8	150	60	2.10	42.00
9	150	90	1.80	36.00

Table 5: Results of Pulp yield for 4M NaOH

S/N	Volume of NaOH (ml)	Time (mins)	Average Pulp Yield (g)	Average Pulp Yield (%)
1	50	30	2.21	44.20
2	50	60	2.03	40.60
3	50	90	1.81	36.20
4	100	30	2.09	41.80
5	100	60	1.81	36.20
6	100	90	1.7	34.00
7	150	30	2.12	42.40
8	150	60	1.86	37.20
9	150	90	1.62	32.40

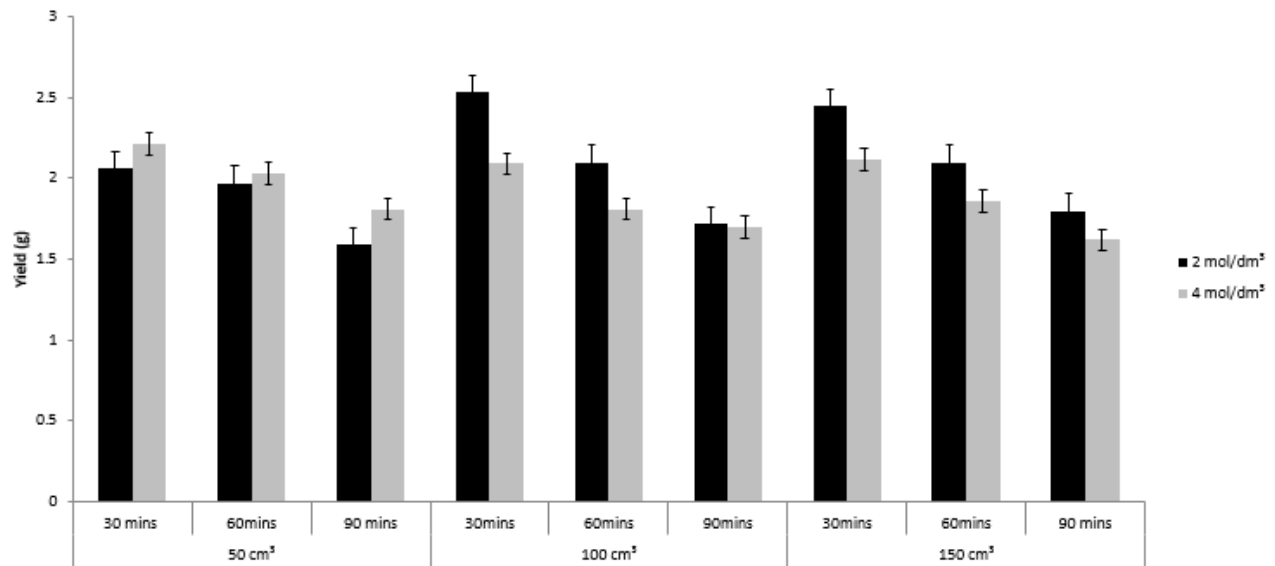


Figure 5: Pulp yield for 2M and 4M NaOH using different time and volume

SEM Analysis

The micrograph (Figure 6) of bleached paper showed lines of cracks (void region), whereas the unbleached paper showed no pores or cracks. As seen in Figure 7, this suggests that bleaching the pulp improved the paper's quality even more for durability.

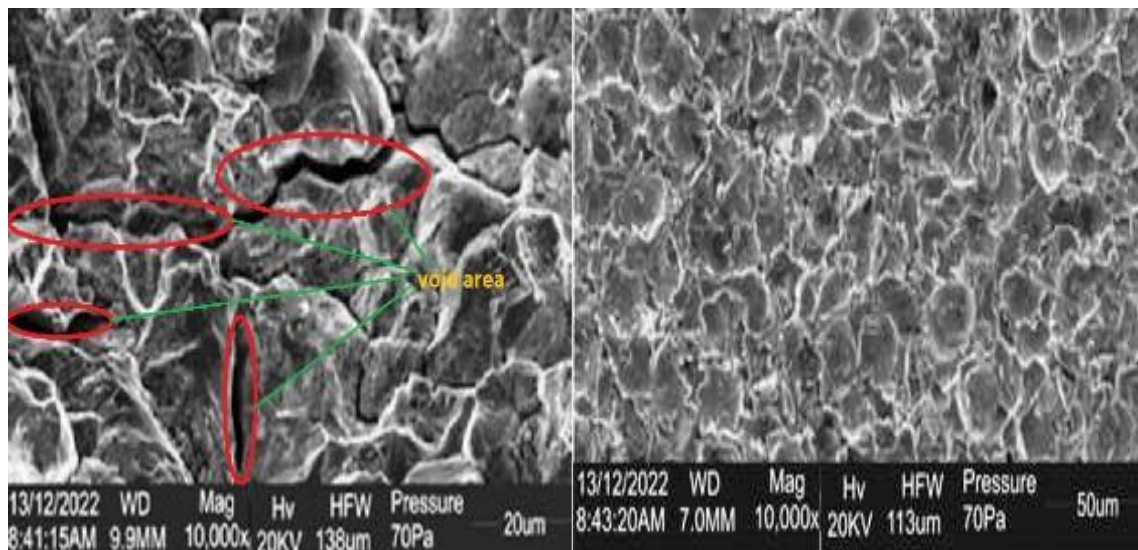


Figure 6: SEM micrographs for Bleached and Unbleached paper



Figure 7: Unbleached and Bleached Paper produced

IV. Conclusion

This research has demonstrated that sugarcane (*S. Officinarum*), a non-woody plant, presents a viable alternative source for paper pulp owing to its long bast fibre properties and significant pulp yield. Both the bast and core fibre from sugarcane bagasse have the capability to be used in pulp and paper production. Nevertheless, the bast fibre in sugarcane bagasse has superior qualities compared to the core fibre. As the demand for paper continues to rise, existing wood supplies may not be adequate to meet this growing need. It is important for industries to embrace non-wood pulp to address the possible shortfall of wood fibre required for paper manufacturing. Natural resources such as wood face considerable pressure due to population growth, making it imperative on a global scale to shift towards sustainable practices to mitigate climate change, reduce environmental threats such as deforestation, promote circular economy principles, and achieve carbon neutrality. This research also plays a role in the advancement of eco-friendly alternative pulping techniques. Producing paper from sugarcane offers a valuable solution for the environment and can help rejuvenate the paper manufacturing sector in Nigeria.

Conflicts of Interest

The authors declare no conflict of interest for the content of this manuscript.

References

1. A. F. Aderounmu and E. A. Adelusi. Axial and Radial Variation of Fibre Characteristics of *Bambusa Vulgaris*. Journal of Scientific Research and Reports, 2019, 24(4): 1-8. ISSN: 2320-0227
2. H. Afra, M. Yousefi, and T. Nishino. Comparative effect of mechanical beating and nanofibrillation of cellulose on paper properties made from bagasse and softwood pulps," Carbohydrate Polymers, 2013, 97(2) 725-730.
3. S.D. Asagekar, and V.K. Joshi. Characteristics of sugarcane fibres. Indian Journal of Fibre & Textile Research 2014, 39(2):180-184
4. I Bektas, A Tutus and H Eroglu. A Study of the Suitability of Calabrian Pine for Pulp and Paper Manufacture. Turk. J. Agri. For. 1999, 23 (3): 589-597.
5. Z. Chen, J. Yi, and D. Feng. Preparation method of corn stalk fibre material and its performance investigation in asphalt concrete. Sustainability 2019, 11(15), 40-50.
6. H.O. Chibudike, N.A. Ndukwe, N.I. Obi, O.A. Adeyoju and E.C. Chibudike. MEA Pulping of Sugarcane Bagasse: Effect of Fiber Morphology and Beating Treatment on Properties of Furnished Paper. American Journal of Innovative Research and Applied Sciences. 2020, ISSN 2429-5396
7. G. Daniel, A Lamesa, and G. Degnechew. Investigation of Fibre Properties of Eucalyptus Globulus grown in FartaWoreda as Potential Source for Pulp and Paper Making, Amhara National Regional State, Ethiopia". Research Square Platform LLC. 2022, DOI: [10.21203/rs.3.rs-2093328/v1](https://doi.org/10.21203/rs.3.rs-2093328/v1)
8. Z.T Egbewole. Investigation into selected wood quality indices of plantation grown *Sterculiasterigera*. Masters Research Submitted in the Department Forest Resource Management University of Ibadan, 2004, 178.
9. Z.T Egbewole, PO Omoake and OJ Rotowa. Evaluation of fibre quality of *Saccharum officinarum* (sugarcane bagasse) as a raw material for pulp and paper production. NSUK Journal of Science and Technology, 2015, 5: (2): 142 – 149
10. D.O. Ekhuemelo, and A.M. Udo. Investigation of Variations in the Fibre Characteristics of *Moringa Oleifera* (Lam) Stem for pulp and paper production. International Journal of Science and Technology. 2016, 5(1): 19-20
11. D. O. Ekhuemelo, V. O. Aidoko and E.T. Tembe. Evaluation of pulp and paper making potentials of *FicusExasperata*Vahl in Makurdi, Nigeria. South Asian Journal of Biological Research. 2018, 1(1): 61-78
12. A.M. El-Sayed, K.H. Hamad, Y. Eid, A. Alaa and A. Mohsen. Production of Paper Using Chemical Pulping Process of Sugarcane Bagasse. International Journal of Industry and Sustainable Development. 2022, 3(1) :57-65
13. P.M. Gopal, N.M. Sivaram, and D. Barik. Energy from Toxic Organic Waste for Heat and Power Generation. Paper Industry Wastes and Energy Generation from Wastes. Woodhead Publishing Series. 2019, Chapter 7: 83-97 doi.org/10.1016/B978-0-08-102528-4.00007-9
14. H. Kirci. Pulping industry. KTU Faculty of Forest Press, No:86, Trabzon 2006
15. M.A. Mahmud and F.A. Rahman. Sugarcane bagasse - A source of cellulosic fibre for diverse applications. J. Heliyon 2021, doi: 10.1016/j.heliyon.2021.e07771
16. A.A. Mayowa (2018) Pulping of Non-Woody Biomass. <http://dx.doi.org/10.5772/intechopen.79749>
17. SA Noah. Fundamentals of Pulp and Paper Manufacture. Fasco Publishers. Ibadan. 2009, 181pp.
18. B. E. Obiora, C.A. Jonah, C. E. Ikenna and N. Christian. Sustainable production and consumption of paper and paper products in Nigeria. 2019, 8:53; doi:10.3390/resources8010053
19. A.O Oluwadare and Z.T Egbewole. Wood Quality Studies in Plantation Grown *Steculia* (*Steculiasetigera*) in the Guinea Savannah, Nigeria. Research Journal of Forestry. 2008, 2: 22-33.
20. M.A. Onilude. Pulp and Paper Industry: A Neglected Goldmine in Nigeria. Inaugural Lecture 2010/2011. University of Ibadan, Nigeria. 2011
21. A. O. Osadare and J. S. Udohitinah. Fibre Characteristics of some Nigerian Raw Materials for Long Fibre Pulp Production. In: Forestry for Urban and Rural Development in Nigeria, Oduwaiye, E. A. (Ed). FAN 23rd Conference, 1993, Pp: 132-138

22. O. J. Rotowa, Z. T. Egbewole, and P. O. Omoake. Evaluation of Fibre Quality of *Bambusa Vulgaris* (Bamboo) as a Raw Material for Pulp and Paper Production. *Production & Agriculture Tech*, (2015, 11 (2): 188-202 ISSN: 0794-521
23. N.A Sadiku, A.O. Oluyeye, and B. Ajayi. Fibre dimension and Chemical Characterisation of Naturally Grown *Bambusa Vulgaris* for Pulp and Paper Production. *J. Bamboo and Rattan*. 2018, 15(1-4): pp. 33-43.
24. A.O Sotannde. Preliminary Investigation into the Fibre Characteristics of *Thaumatococcus daniellii*. MSc. dissertation submitted to the Department of Forest Resource Management for the award of Bachelor of Forestry Degree, University of Ibadan. 2000, Pp 120.
25. Y. Li and X-Q. Dai *Biomechanical Engineering of Textiles and Clothing*. Woodhead publishing. 2006, ISBN 978-1-84569-052-6
26. R. Young, R. Kundrot and D. Tillman. Pulp and Paper, in *Encyclopedia of Physical Science and Technology*, Third Edition ed., United States of America, Academic Press, 2003, 249-265.
27. ASTM International (American Society for Testing and Materials): Specific gravity of wood and wood -base materials designated, Method b, volume by Immersion, (D 2395-69); Standard method of tests for water solubility Method A and B, (D1110-68); ash, (D1102-72); one percent caustic soda solubility, (D1109-72), and moisture in wood, (D1101-77).
28. Technical Association of Pulp and Paper Industry (TAPPI). Acid insoluble lignin in wood and pulp Designated T22 om-98.169 (1998).