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Preliminary Investigation of Fibre Dimensions and Morphological Properties of Pineapple Crowns and Corn Sheaths: Renewable Resources in Paper Production

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***Abstract-** Fibre characteristics are crucial parameters in determining the suitability of biomasses in paper production, impacting various aspects of the process and final product quality, particularly, paper strength and durability. This study investigated the fibre dimensions of pineapple crowns and corn sheaths and explores their potentials for paper production. Pineapple crowns and corn sheaths were macerated with the solution of acetic acid and hydrogen peroxide heated for 2hrs, the heated solution caused the agricultural residues to disintegrate into slivers. The slivers were examined under a micrometer mounted on an Olympus light microscope (Standard 25). The microscopic examination of the slivers showed the fibre dimensions such as fibre length (FL), fibre diameter (FD), lumen width (LW) and cell wall thickness (CW) of the strands. The morphological properties such as : runkel ratio = 2 (cell wall thickness)/ lumen width, flexibility coefficient = lumen width/ fibre diameter x 100, rigidity coefficient = (cell wall thickness)/ (fibre diameter) x100 and slenderness ratio or felting power = fibre length / fibre diameter were derived using the fibre dimensions. Independent sample student t-test of GraphPad Prism, version 8.2 was used to compare the mean values for significant difference at p<0.05. 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, the values in the range of TAPPI standard values for long fibres as found in soft woods. Corn sheaths exhibited fibre length of 1.67 mm, fibre diameter 49.31 µm, lumen width 36.67 µm and cell wall thickness of 5.75 µm as found in hardwoods.*

***Keywords:** Fibres, Dimensions, Corn Sheaths, Pineapple Crowns, Paper*

I. INTRODUCTION

The world population is increasing with increase in demand for papers and paper products. As the demand for papers is steadily increasing, the paper industry is expanding on a daily basis and the demand for paper has exceeded 400 million tons per year globally; according to the Environmental Paper Network (EPN, 2018). However, the expansion in the paper industry raises significant environmental concerns due to its heavy reliance on wood fibres as raw materials. Issues such as deforestation, climate change, loss of biodiversity, soil erosion, and health problems are all associated with the pulp and paper sector. Paper production consumes a significant and greater part of the world's wood forests (Odjugo, 2010). Approximately, 35% of the global forest woods were utilized for paper production in 1983, a figure projected to increase to 70% by 2030 (Statista, 2024). Despite the increasing effects of deforestation on climate change as a result of forest trees removal, and several international treaties to mitigate climate change and other effects of deforestation, most paper mills, globally, still depend on the forest woods as main raw materials for paper production. Due to the concerns about the threat of deforestation, CO2 emissions and climate change, there is need to focus on alternative non wood fibre sources such as pineapple crown and corn sheath wastes.

These agricultural by-products considered as wastes, have been identified as potential sources of natural fibres for various industrial applications, especially for paper production. The utilization of these wastes could provide sustainable alternatives to wood fibres predominantly used for paper production. However, the physical properties of pineapple crown and corn sheath fibres, particularly, their dimensional characteristics and morphological properties, are crucial factors that influence their stability for paper production. Fibre dimensions, including fibre length , fibre diameter, lumen width and cell wall thickness, play a significant role in determining the strength and processing behaviours of natural fibres for paper production. Understanding the fibre dimensions of pineapple crowns and corn sheaths is essential to optimizing the processing conditions, predicting their performance in paper production.

II. MATERIALS AND METHODS

2.1 Collection of Raw Materials

Pineapple crowns and corn sheaths were collected from neighbouring farms and local markets around Mowe and Ofada, Ogun States, Nigeria.

2.2 Hot Maceration of Pineapple Crowns and Corn Sheaths

Pineapple crowns and corn sheaths were collected, dried and cut into strands of 1 cm x 2mm x 2mm each. The strands were put in two different beakers, one for pineapple crowns and the other for corn sheaths. The two beakers each containing the strands of pineapple crowns and corn sheaths separately were 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 beakers were placed 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.

2.3 Microscopic Examination of Pineapple Crowns and Corn Sheath Fibres.

After hot maceration was done, microscopic investigations and measurements of fibre dimensions including fiber length, fiber diameter, lumen width, and cell wall thickness were performed under an Olympus light microscope (Standard 25) at 80x magnification using a stage micrometer and eyepiece graticules and transparent overlays with scale lines. Derived morphology properties sush as : runkel ratio = 2 (cell wall thickness)/ lumen width, flexibility coefficient = lumen width/ fibre diameter x 100, rigidity coefficient = (cell wall thickness)/ (fibre diameter) x100 and slenderness ratio = fibre length / fibre diameter.

III. RESULTS AND DISCUSSION

Table 1presents the fibre dimensions of both pineapple crowns and corn sheaths. 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, the values are in the range of TAPPI standard values for long fibres as found in soft woodsg. Corn sheaths exhibited fibre length of 1.67 mm, fibre diameter 49.31 µm, lumen width 36.67 µm and cell wall thickness of 5.75 µm, the values in the range of TAPPI standard values for short fibres as found in hard woods. Table 1 reveals that pineapple crown and corn sheath fibres have good potentials and are suitable for paper production. The potentials of corn sheath and pineapple crown fibres in paper making are determined by their fibre characteristics such as fibre length (FL), fibre diameter (FD), lumen width (LW) and cell wall thickness (CWT). Fibre length is the most important parameter in fibre dimensions. Fibres are classified as long fibres and short fibres, according to TAPPI standards. Fibre length ≥ 2 mm are considered to be long fibres and preferred in paper production as they produce quality papers (Udotina and Oluwadare, 2011). Fibre length < 2mm are classified as short fibres according to TAPPI standards. The fibre length, fibre diameter, lumen width and cell wall thickness exhibited by both corn sheaths and pineapple crowns fall within the acceptable range for TAPPI standards for short and long fibres and also align with Fagbemigun et al., (2016). Due to the short fibre length of 1.67 mm exhibited by corn sheaths and the long fibre length of 2.54 mm exhibited by pineapple crowns, both can be used to produce quality papers since they possess the fibre characteristics of both soft woods and hard woods which are relied on as fibre sources in the paper industry (Fagbemigun, 2014). Fibre diameter is another critical parameter considered to play a significant role in pulp and paper production. The fibre diameter exhibited by corn sheaths and pineapple crowns were 49.30 and 35.19 µm respectively (Table 1). The diameter of the fibres has impact on the pulp yield, the larger the fibre diameter, the more the pulp yield (Dutt *et al*, 2011). Lumen width also plays a significant role in pulp and paper production. As presented in Table 1, pineapple crown fibres and corn sheath fibres exhibited lumen width of 31.05 µm and 36.67 µm respectively, these fall within the values of fibres that produce papers with strength and durability (Fagbemigun, 2016, Dutt etal, 2011). Fibre cell wall thickness is another important parameter in pulp and paper production. Pineapple crown fibres and corn sheath fibres exbitited cell wall thickness of 8.96 and 5.75 µm respectively. Fibres with thin cell walls tend to produce papers with more flexibility and require less chemical and energy during pulping process (Fagbemigun, 2016). The values obtained in this study are similar to the values presented by Dutt et al. (2011) and (Fagbemigun, 2016). Independent student sample t-test was used to compare the mean values for significant difference at p<0.05 (Table 3). The study reveals that fibre characteristics are important parameters to be considered in the utilization of any fibre based materials for paper production.

Table 2 reveals the morphological properties of pineapple crowns and corn sheaths, the values for runkel ratio, slenderness ratio, rigidity coefficient and flexibility coefficient for both pineapple crown and corn sheath fibres. It shows that pineapple crown fibre exhibited runkel ratio value of 0.558 while the runkel ratio value exhibited by corn sheath fibre was 0. 314 both values are less than one (< 1), these values align with what was reported by Udotina and Oluwadare (2011) as the acceptable runkel ratio value for good fibres for pulp and paper production. The results shows the desirable values for runkel ratio of fibres for quality papers according TAPPI standards that runkel ratio ≤ 1 is an indication that the biomass will be highly palpable and excellent to produce high quality papers while ratio > 1 is also a good value for paper production (Ekhuemelo, 2013). For slenderness ratio as shown in Table 2, pineapple crown and corn sheath fibres exhibited 33.47 and 71.99 respectively; these values conform to what was reported by Fagbemi *et al.* (2016). Slenderness ratio > 33 are considered to be of quality fibres for quality paper production. Fagbemigun affirmed that fibres with slenderness ratio > 33 bond better and are considered good fibres for paper production (Syed, Zakaria and Bujang, 2016). Table 2 also shows that corn sheaths exhibited flexibility coefficient of 88.13 while pineapple crowns exhibited 73.50, both values are higher than what was reported for kenaf fibres by Udotina and Oluwadare (2011) which make them to be more preferable for paper production. The rigidity coefficients exhibited by corn sheath and pineapple crown fibres were 11.50% and 25.47% respectively (Table 2). Research findings have shown that the desirable rigidity coefficient for soft woods and hardwood fibres are between 13 to 20 and 15 to 35 respectively. The rigidity coefficient exhibited by corn sheath fibres is in the range of that of soft woods while the rigidity coefficient exhibited by pineapple crown fibres is in the range of that of hardwoods which show that both corn sheath and pineapple crown fibres are good for pulp and paper production (Dutt et al., 2011). Data collected were subjected to statistical analyses using Independent Sample Student t-test of GraphPad Prism, version 8.2. Significant difference (P<0.05) existed between the values for fibre dimensions and derived morphological properties of pineapple crowns and corn sheaths. These two agricultural wastes exhibited fibre characteristics desirable for paper production and can serve as alternative fibres sources to wood fibres.

Table 1: Test for Comparison of Fibre Dimensions of Pineapple Crowns and Corn Sheaths

Test samples	Fiber dimensions			
	F L (mm)	F D (µm)	LW (µm)	CWT (µm)
Pineapple Crowns	2.54 ± 0.36^{a}	35.19 ± 23.67^{a}	31.05 ± 15.40^{a}	8.96 ± 11.46^{a}
Corn Sheaths	1.67 ± 0.60^{b}	40.30 ± 26.64^{a}	36.67 ± 20.61^{a}	5.75 ± 1.53^{a}

Mean ± standard values with different superscripts in a column differ significantly at p<0.05.
FL - Fibre Length, FD – Fibre Diameter , LW – Lumen Width , CWT - Cell Wall Thickness

Table 2: Test for Comparison of Morphological Properties of Pineapple Crowns and Corn Sheaths

Morphological Properties

Test samples	Runkel Ratio	Slenderness Ratio	Rigidity Coefficient (%)	Flexibility Coefficient (%)
Pineapple Crowns	0.56±0.00 [a]	71.99±0.05 [a]	25.47±0.03 [a]	73.50±0.05 [a]
Corn Sheaths	0.31±0.01 [b]	33.47±0.01[b]	11.50±0.10 [a]	88.13±0.02 [a]

Mean ± standard values with different superscript in a column differ significantly at $p<0.05$.

IV. CONCLUSION

In conclusion, this study has successfully investigated the fibre dimensions and morphological properties of pineapple crown and corn sheath wastes, revealing their potentials for paper production. The study revealed the fibre dimensions (fibre length, fibre diameter, lumen width and cell wall thickness) exhibited by pineapple crown and corn sheath fibres. Pineapple crown and corn sheath fibres exhibiting fibre length of 2.54mm and 1.67mm respectively indicate their potentials as valuable alternatives to traditional wood fibres. These fibre dimensions suggest that pineapple crown and corn sheath fibres are suitable for paper production. This research contributes to the growing body of knowledge on sustainable non wood fibre sources, highlighting the potentials of pineapple crowns and corn sheaths, which are generally considered as wastes, as valuable non wood fibres. By optimizing processing conditions and fibre extraction methods, industries can harness the unique properties of these fibre based waste to produce quality papers.

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