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Pulp Extraction and paper production from banana pseudostem and its characterization

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Abstract: Banana is one of the popular plant and is widely cultivated in Africa due to its benefit to mankind. Extraction and utilization of banana fiber for making paper and its equivalent is an effective and economics means of reducing biomass in the society, reducing deforestation and prevention of environment hazards resulting from paper making industries. In this paper, extracted pulp from banana pseudostem was characterized and the Lady Finger paper type has the highest paper strength and folding endurance with 20 g/mm^2 and 1.68 respectively. FTIR analysis of the paper types indicated the presence of different functional groups: hydroxyl (3352 -3437), Amide (1630-1631), Carboxylate (1317-1371) and Transition metal carbonyl group (2009-2044). This innovation would reduce deforestation by paper making industry, boost small and scale industry and increase employment.

Keywords: Pulp, Paper, Non-convectional fibre, FT-IR characterization

1.0 Introduction

The paper products industry is big business generating over $200 billion, Global paper use has increased by 400 % in the last 40 years [1]. The global demand for paper products is significant as evidenced by the more than 350 million tons produced annually. The papermaking process is complex and has far-reaching environmental impacts creating major health issues and environment degradation [2].

Although, non-woods are originally used for paper making in early 1970s, the conventional paper is derived from wood, a forest resource and the paper industry is mainly depending upon forest resources. It was reported that 70 % of global wood fibres were obtained from roundwood and chips in 2004 while non-wood pulp was said to have 5 % capacity of the total paper making capacity[3]. Deforestation is rampaging the world causing global warming, climate change, desertification and loss of biodiversity [4]. A convergence of environmental concerns and shortage constraints has led to an increase in non-wood fibre production for pulp and paper industry [5]. It is therefore important to search for alternative cellulose containing resources as raw material for paper making using environment friendly technology. The usage of non-wood fibre materials for pulp, paper and cellulose based is a way of reducing the deforestation and protection of the environment. The renewed interest in non-wood fibre sources offer several advantages in the pulp and paper industry:

i. it offers a renewable source (annual) of raw material compared to the long growth cycles for wood;
ii. the lower lignin content in non-wood fibre implies that chemical pulping process will require relative environment friendly approach compared to the wood pulping; and
iii. non-wood fibre can be used in making every grade of paper and fibre-board and composite materials.

However, non-wood fibre sources have it own challenges which include:

i. seasonal availability;
ii. handling problem resulting from their high-volume-low-density; and
iii. large amount of dirt and earth materials (silica) which have to be removed during processing.

Banana fiber can be an alternative raw material for paper making such as tissue, bloating, tracing and writing printing paper [6]. Banana plant (*Musa sp.*) is planted for its highly nutritious fruits [7] and is more easily digestible than many other fruits including apple [8]. Banana is a major fruit crop of the tropical and sub-tropical regions of the world grown on about 8.8million hectares [8]. Fiber is extracted from the leaf sheath or pseudostem of the banana plant and the use of “Banana” fiber for textile and other purpose as natural material is a new concept. In the recent past, banana fibre had very limited applications and was primarily used for making items like ropes, mats and some other composite materials. With the increasing environmental awareness and growing importance of unfriendly fabrics, banana fibre has also been recognized for all its good qualities and now its application is increasing in other fields including garment making and home furnishings [9].

The physical morphological and chemical characteristics of different *musa* species were studied by [10]. In spite of the various uses of banana plants, large portion of its biomass are dumped as wastes on the farms and in the neighborhood causing environmental hazards and ecosystem imbalance. The extraction and utilization of banana fibers for paper making is an effective and economic means of reducing this wasted biomass and reduce de-forestation activity resulting from papermaking industry. This aim of the study was to extract pulp from the pseudostem, make paper from the extracted pulp and characterized the paper made from different banana cultivars.

2.0 Methodology

2.1 Sample collection

Three different banana cultivars: Banana, Ladyfinger and Plantain pseudostem farm wastes were obtained from local farms in Ede area of Osun State. Cleaned kitchen knife was use to split the each cultivar pseudostem into layers. The layers were thereafter sun dried and cut into smaller pieces in preparation for cooking.

Figure 1: Dried Banana varieties pseudostem chips, A = Banana, B = Plantain, C = Lady Finger

2.2 Pulp Extraction

The pulp was extracted through:

i. Cooking: The dried fibre of each banana cultivar (50 g) was weighed into glass beakers and cooking liquor (12 % NaOH) was added (1:5) ratio and coked. The cooking liquor volume in the digester was maintained by adding hot water. The digested fibre (pulp) was rinsed with tap water till the mixture is neutral. The yield of pulp was gravimetrically determined after oven-dried [11]

ii. Pulping: The cooked fibers was soaked and thoroughly rinsed with water to remove the residual sodium hydroxide. The alkali-free fibre was then transferred into a blender and cool clean water was added. The blending was done until almost consistency solution was obtained. The blended solution was filtered using a muslin cloth. The pulp obtained was dried.

iii. Pulp bleaching: The pulp was bleached by soaking it in 2.5 % of chlorine water for 2 hours. The bleach pulp was thereafter was rinsed free of chlorine.

Figure 2: (a) Wet pulps (b) Dried pulp

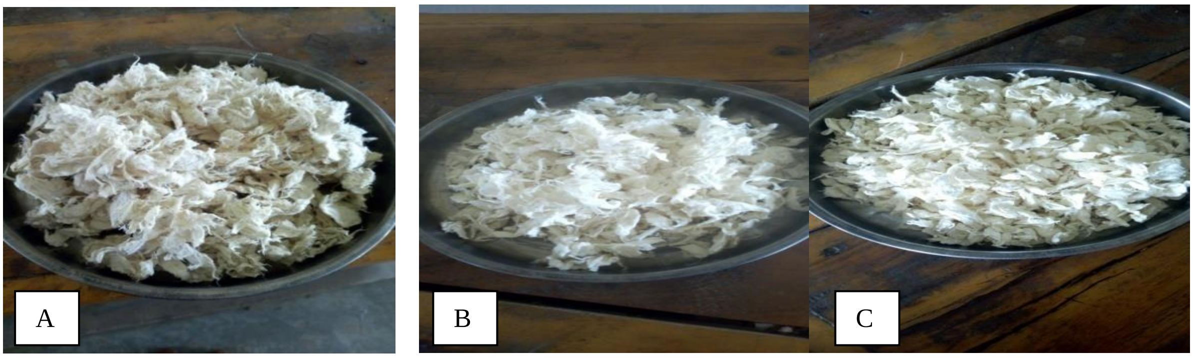


Figure 3: Bleached Pulp, A = Plantain, B = Banana, C = ladyfinger

2.3 Paper sheet making

The bleached pulp (15 g) was weighed and blended (500 ml of water and 1% of CMC) to separate fibers into consistency solution. The blend was poured into mold and deckle in a bowl filled with 2/3 water. Mold and deckle was removed from the bowl and it was allowed to drain completely before the deckle was removed.

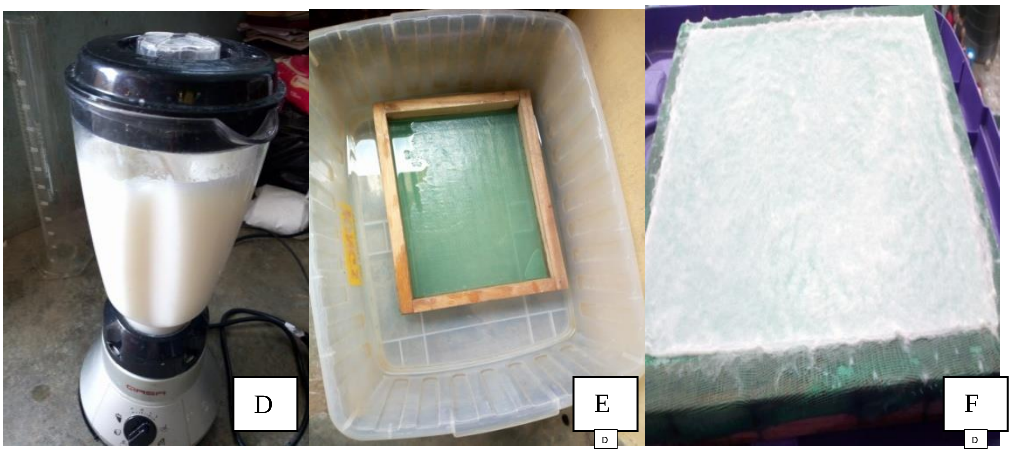


Figure 4: Sheet making process; D = Pulp blending, E = pulp pouring, F = Sheet draining

2.4 Paper and pulp characterization

i. Percentage pulp yield:

The weight of different wet pulp was measured as with the aid of analytical balance.The crucible was weighed as W_1. The pulp was transferred into the crucible and it was weighed as W_2, the sample was dried in oven at 60 ^{0}C for 1hour, cooled to room temperature in the desiccators and weighed. The crucible was returned into the oven for 30 minutes, cooling and weighing and this action was repeated until constant weight W_3 was obtained. The pulp yield was calculated using this formula:

$$\text{Pulp yield} = \frac{W2-W3}{W2-W1} \times 100$$

ii. Pulp FT-IR Characterization

Extracted and cleaned pulp from each banana cultivars was grinded into powdery form with mortar and pestle. Sieved pulp powder (0.5 g) was mixed with potassium bromide crystals and pressed into a disc. The formed disc was inserted into FTIR machine for analysis.

iii. Paper strength: The paper was hold with two retort stands and incremental weights were put on the retort-held paper and allowed to stand for five minutes before the weight increase. The weight held by the paper before tear is taken as the strength of the paper. The experiment was performed in triplicates for each paper type.

iv Folding Endurance: Different papers was folded backward and forward about the same line in a complete oscillation, the number of double folds that is required to make a paper break was use to determine the paper folding endurance under a standard weight.

$$F = \text{Log}\,10d$$

v. Smoothness: Different sheet of paper was run through a fingers, the smoothness of each paper was noted.

3.0 Results

Different banana variety pseudo-stem was processed into fibre, pulp was extracted bleached and used to produce paper shown in the figure 5 below. The paper sheets produced from the extracted pulp from the banana variety were subjected to mechanical tests. Out of the three paper types, Lady Finger paper has the highest paper strength and folding endurance with 20 g/mm^2 and 1.68 respectively as shown in figure .(4.2) which implied that Lady Finger banana paper has highest durability and strength than the other paper types.

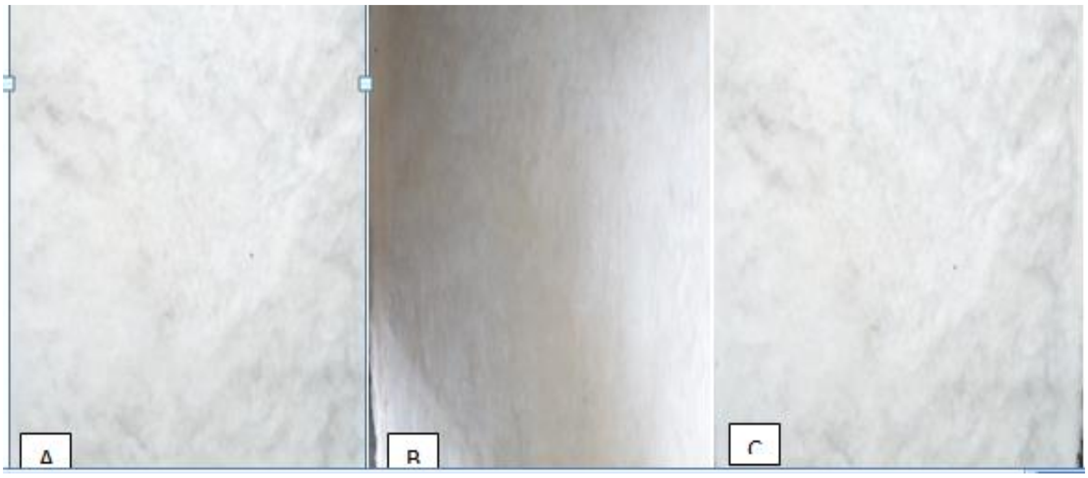
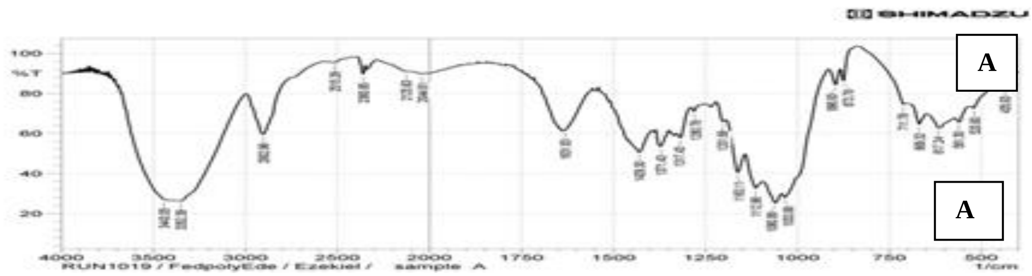


Figure 5: Different paper produced: A = Lady finger Paper, B = Banana Paper , C = Plantain Paper



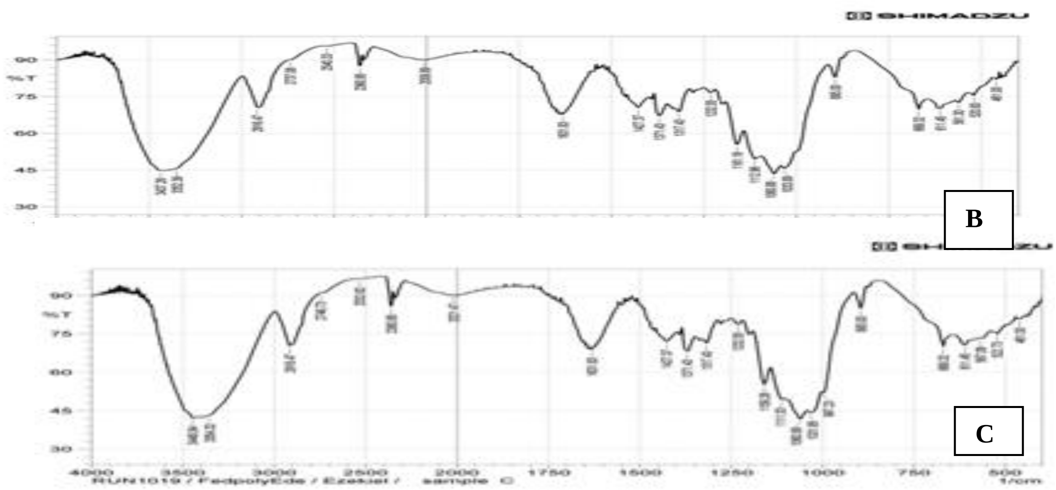


Figure :FT-IR Spectra of Banana Species Pseudostem Pulp: A = Plantain pulp, B = Banana pulp, C = Lady Finger pulp.

The functional groups present in the pulp samples were determined in order to estimate their chemical compositions. The FT-IR spectra of the three pulp types; banana, plantain and Lady (fig.) Finger showed different functional groups which are hydroxyl (3352 -3437), Amide (1630-1631), Carboxylate (1317-1371) and Transition metal carbonyl group (2009-2044). The hydroxyl group has the highest absorbance of all the functional groups present in the three pulp types (57.5, 34.5 & 37) followed by carboxylate (37.5, 16.5 & 16), Amide (21, 17 & 16) and Transition metal carbonyl (5, 5 & 6).

Table :FT-IR Functional group frequency bands of Banana pulps

Frequency	Functional group	Sample Peak band	Peak Type
3352-3437	Hydroxyl	A = 57.5 B = 34.5 C =37	Strong
1317 -1371	Carboxylate	A = 37.5 B = 16.5 C = 16	Weak
1630-1631	Amide	A = 21 B = 17 C =16	Strong
2009-2044	Transition metal carbonyl	A = 5 B =5 C =6	Weak

Conclusion

The banana variety biomass (banana, plantain and Lady Finger pseudostem), a waste resource has been made into valuable product: pulp and paper using a sustainable technology with little impact on the environment. This technology can be converted into a commercial venture by micro and small scale enterprises. The raw material for this valuable product is readily available and the production involved the use of simple chemical (sodium hydroxide) and apparatus. All these could make the paper production technology a simple and easily adopted process with less impact on the environment especially deforestation.

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