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Preparation and Characterization of the Irradiated Banana Paper

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ABSTRACT

Every year, the amount of deforestation is increasing to meet the demand for paper, and this affects environmental pollution and global warming. The presence of fungi on paper can pose a health risk and degrade paper fibre's cellulose. This study was carried out to produce paper from banana stems and recycled paper, and the effects on banana paper and recycled paper were studied before and after radiation. The paper's surface morphology, functional groups and surface roughness were observed and characterised using Opto Digital Microscope, Ultraviolet-Visible Spectroscopy and Atomic Force Microscope. The result indicates there were absorption peaks at 210 to 290 nm for non-radiated paper and 355 to 365 nm for irradiated paper, and the presence of carbonyl and hydroxyl was found in the samples. The surface morphology and roughness were changed due to gamma radiation-induced and caused degradation on the fibre. Banana paper has a better structure and properties than recycled paper, and it will help the pulp and paper industry produce biocompatible, biodegradable and environmentally friendly paper.

1. Introduction

Paper can be made from any fibre, from wood or non-wood fibre and from old cloth to grass clippings [1]. Natural fibre, such as banana fibre, has many advantages, such as low density, high stiffness and high disposability and renewability. Recycled paper is also technically eco-friendly and secure to be used [2]. Fungi can decrease the function of the cellulose fibre and can cause spots or stains on paper, and this will affect the fibre of the paper [3]. There are many ways to avoid the disinfection of fungi, and one way is through paper radiation [4].

The pseudostem is the central part of the banana plant as it serves three primary functions in the tree: to hold the glass, transport water and minerals and act as food storage [5]. The banana plant contributes various polymers such as cellulose, hemicellulose, pectin and lignin. Polymers provide fibre with strong mechanical properties. As fibre is essential for paper making, the fibre needs to be firm and strong [6].

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Recycling is one of the processes that help maintain the environment's cleanness. Many advantages can be obtained if the recycling process can be done; for example, natural resources are saved, emissions are decreased, and the burden of solid waste can be reduced. Recycling can create employment and attract investments, increasing economic growth [7].

To maintain the environment and reduce the cost of pulp and paper production, it is essential to find other alternative techniques to recover or improve virgin or recycled paper to increase the life span of the paper. At the same time, the paper can stand with strength and is not harmful to use, especially free from fungi and bacteria [8]. The durability and resistance towards the paper's environmental stress are mainly independent of the paper's mechanical properties. The tensile strength of the paper is related to the ability of the paper to endure the tension condition, and the tensile strength of the paper between radiated and irradiated is also different [9].

The objective of this study is to observe the surface morphology of paper using an Opto Digital Microscope. Next, to investigate the effect of radiation due to the surface roughness and absorption properties of paper using Atomic Force Microscopy (AFM) and ultraviolet-visible (UV-vis) spectroscopy to compare the structure and effect of radiation between the banana paper and the recycled paper. In this research, banana and recycled paper were compared, sodium hydroxide acted as a bleaching agent and aloe vera was used to avoid entanglement between fibres.

2. Methodology

Banana stem, recycled paper, aloe vera and sodium hydroxide (NaOH) were obtained from Sigma-Aldrich. Banana stem and recycled paper were boiled with 12 to 15 % NaOH. After that, the banana stem and recycled paper were blended until they became pulp with aloe vera. For recycled paper, do not use aloe vera. The pulp was put into mould and dried under sunlight for two days. For Atomic Force Microscope (AFM) and Opto Digital Microscope, the paper was cut into 10 cm x 10 cm for characterisation. For UV-Vis spectroscopy, five samples are prepared with different concentrations of NaOH (0.2, 0.4, 0.6, 0.8 and 1.0 M).

3. Results and Discussion

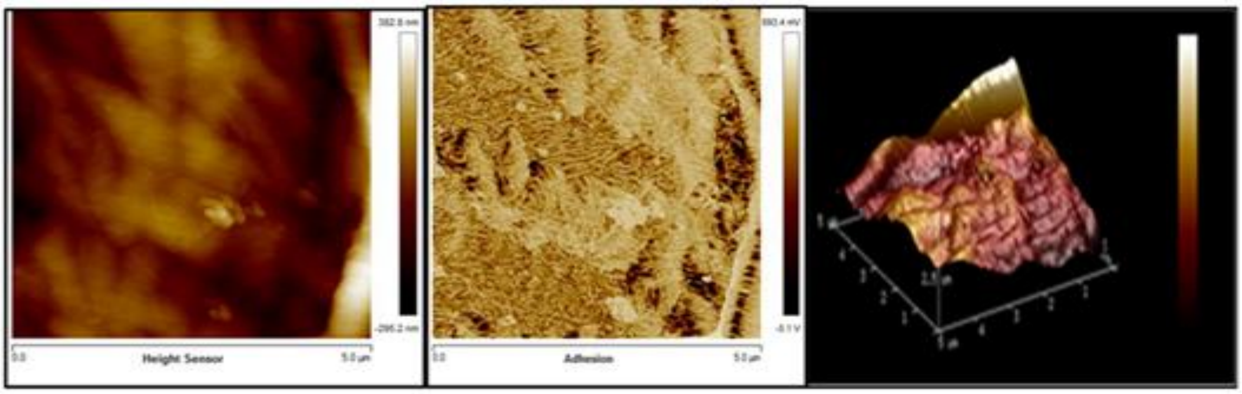
3.1 Atomic Force Microscope (AFM)

The aim of the study on the effect of irradiation with various lignocellulosic is to improve accessibility to solvents, chemical reagents or enzymes and increase cellulose dissolution capacity can be increased for its subsequent processing or the extent of cellulose enzymatic hydrolysis. Non-cellulosic components are also significantly affected by irradiation as well as their respective interactions within the fibre structure; for example, hemicelluloses, pectins and lignin are located within the cell wall structure and in between elementary fibres, and waxes present at the fibre surface.

Researchers [10] assumed the formation of covalent bonds between lignin and starch increased the hydrophobicity of the films as well as the self-cross-linking of lignin during irradiation. Significant morphological changes and damages have also been reported after irradiation of natural fibres. The evidence of cell walls and middle lamellae degradation in wood and recycled fibres can be seen in AFM observation; there are modifications in the porous structure, and the total pore volume, especially the volume of tiny pores, increased significantly.

Many advantages can obtained from the treatment of gamma radiation. Firstly, a complex structure that is difficult to dissolve in the acidic solution can be removed from the fibre surface. Therefore, the percentage of cellulose content increases. As the percentage of the cellulose content increases, the moisture absorption rate also increases. This is because the chemical structure of cellulose contains three hydroxyl groups, which form hydrogen in the macromolecular cellulose structure.

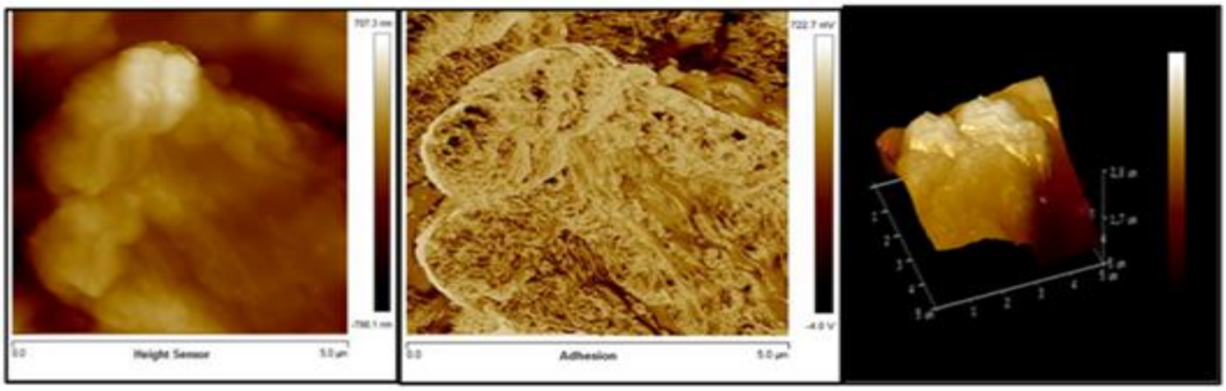
The raw banana paper exhibits a rough topography due to the fibre's presence of hemicellulose, lignin and waxy components [11]. Hemicellulose were located within and between the cellulose fibrils and was integrated into the cellulose structure. The pulp or fibre with high hemicellulose content had a low maximum tear index but a high maximum tensile strength [12].



(a) (b) (c)

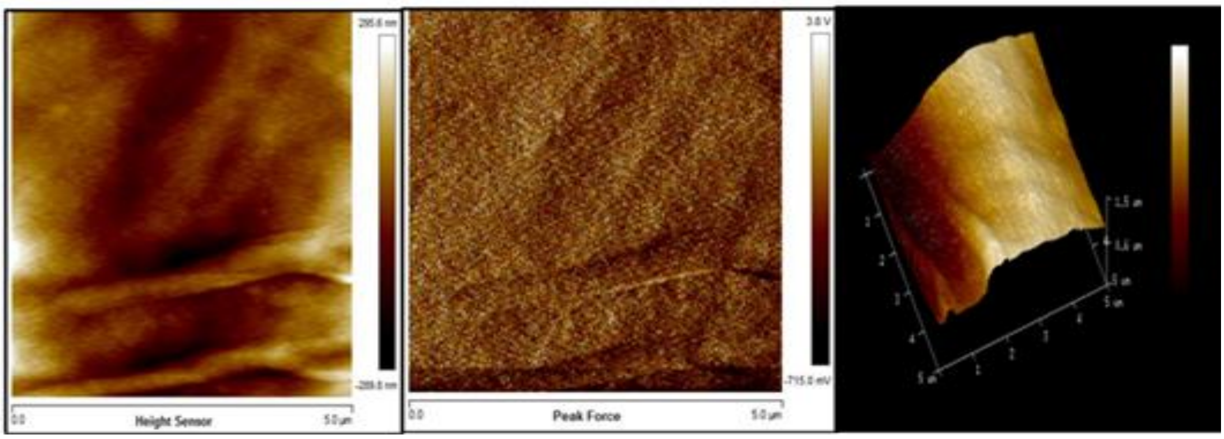
Fig. 1. AFM images of banana paper (a) Height image, (b) Phase image and (c) in 3D form

The recycled paper consisted of a criss-crossing, porous structure and smooth surfaces without a hierarchical roughness structure, which was formed via the papermaking process, and this component does not consist of banana paper [13]. Figure 2 (b) shows the swelling of the fibres in recycled paper, where the water penetrates the fibre through the pores, then breaks the secondary interactions between cellulose macromolecules, and it is adsorbed into the fibre by hydrogen bonds [14].



(a) (b) (c)

Fig. 2. AFM images of recycled paper (a) Height image, (b) Phase image and (c) in 3D form

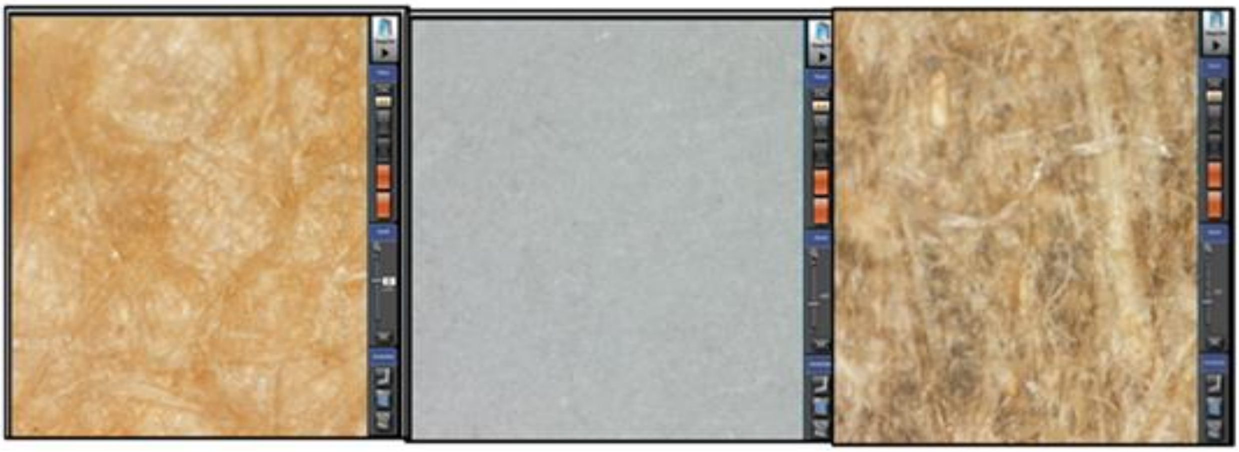


(a) (b) (c)

Fig. 3. AFM images of radiated banana paper (a) Height image, (b) Phase image and (c) in 3D image

3.2 Opto Digital Microscope

Banana paper shows in Figure 3 that long-wrapped fibre bundles and rough surfaces were observed. The cellulosic fibres surround the surface of cellulose fibres, acting as "natural binders”. Long-fibre manufactured papers generally present better strength properties than those made with short fibres [15]. Recycled Paper does not show a homogeneous dispersion of fibres in the composite; fibres tend to agglomerate and come in contact with each other due to closing the pores and holes due to fibre extraction, and as a consequence, the recycled paper has poor fibre–matrix adhesion rather than in banana paper. There is space between the fibres due to the low hemicellulose content in the recycled fibre. The surface of recycled paper is smoother. However, severe fibre breakage takes place upon reprocessing [16].



(a) (b) (c)

Fig. 4. Opto Digital Microscope images for (a) Banana paper, (b) Recycled paper and (c) Irradiated banana paper

Based on Figure 4(c), the gamma radiation-induced modification in the cellulose fibre arrangement changed the fibre's colour into dark or brown, probably due to the formation of chromophores groups or colour centres in the cellulose. The colour centre formation of macromolecular materials may be partly inherent from a combination of trapped radicals and permanent structural changes in the macromolecules, which include conjugated chromophores. There was probably some cleavage on the cellulose molecules, which affected the natural fibre more than the recycled fibre, but the recycled fibre was also affected by radiation. However, the extension was insufficient to cause significant modification in the fibre network of the paper.

The scission of the polymer chain is the main ionising radiation effect on cellulose and other polysaccharides. The scission of the polymer is caused by the degradation of the physical chemistry properties of the polymer, including structural and mechanical strength, solubility in different media, and reactivity. The degradation process can occur in many ways if treated with ionising radiation. For example, degradation in a macromolecule, by random split without crosslinking, prevails when the cellulose and other polysaccharides. Chain scission generally dominates when polymers are irradiated in the presence of oxygen. Oxygen plays a vital role in radiation efficacy; the greater the chance of oxygen interaction, the longer the irradiation period, thus, the greater the indirect effect.

Acid hydrolysis is the primary chemical reaction that occurs in paper degradation. When hemicellulose is present in the paper, it hydrolyses faster than cellulose, which is the process where acid hydrolysis occurs. Fibre strength will be lost as the link between the fibre is also lost, which will affect the paper's mechanical properties.

3.3 Ultraviolet-Visible Spectroscopy

The entire samples exhibit the absorption band in the 219 to 230 nm range. This range indicates the presence of a phenolic group as the lignin compounds in the paper exhibit antioxidant activity, and this activity was found for various synthetic polymers, rubber and foodstuffs. The presence of unsaturated substituents on α-carbon of a side chain, for example, a carbonyl group or double bond, causes absorption in the form of broad peaks or shoulders and thus lignin colours [17].

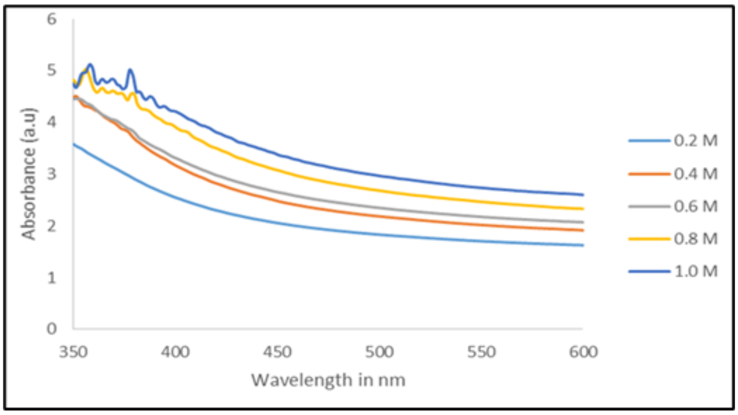


Fig. 5. Graph of irradiated banana paper with different concentrations of sodium hydroxide

All the samples shown in Figure 5 have an absorption peak at 355 to 365 nm, revealing the presence of π-π* transition. This transition occurs from the C=O bond; this bond is part of the carbonyl in the cellulose fibre. Specific ionisation lignin samples show a shoulder or a maximum near 365 nm, which agrees well with alkaline solutions in the maxima spectra of model compounds. The peak around 365 nm in the irradiated paper is composed of peaks due to p,p-dihydroxystlibenes where λ max= 365 nm and phenolic α-carbonyl units where λ max > 350 nm [18].

3.4 Effects of Radiation on Paper

Figure 6 shows an image of irradiated banana paper under an Opto Digital Microscope. The gamma radiation-induced modification in the cellulose fibre arrangement changed the fibre's colour into dark or brown, probably due to the formation of chromophore groups or colour centres in the cellulose. The colour centre formation of macromolecular materials may be partly inherent from a combination of trapped radicals and permanent structural changes in the macromolecules, which include conjugated chromophores [19].

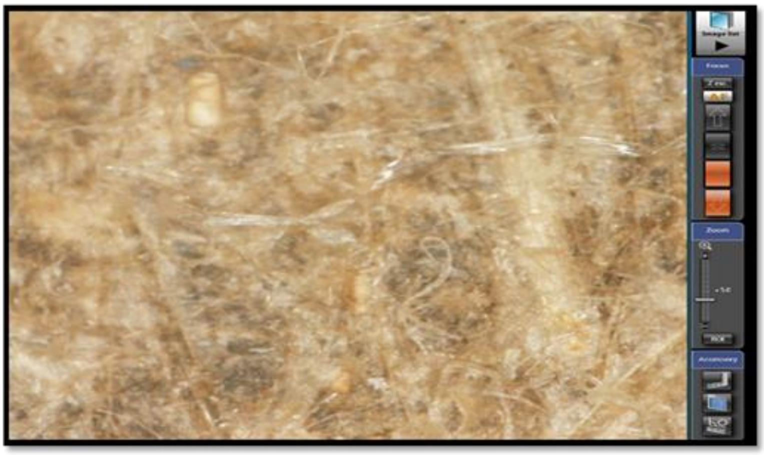


Fig. 6. Image of irradiated banana paper under Opto Digital Microscope

4. Conclusions

According to the data obtained, it can be concluded that the banana and recycled paper had been produced using environmentally friendly products, and the paper was radiated to study its effect on the paper. In this study, the banana paper and recycled paper showed better structure and impact of radiation than the recycled paper. Based on the results from the characterisation of UV –Vis spectroscopy, the absorption peak at 210 to 290 nm for non-radiated paper and 355 to 365 nm for irradiated paper and the presence of carbonyl and hydroxyl were found in the samples and banana paper shows a good effect of radiation by the arrangement of molarity. The surface morphology and roughness of the banana paper and recycled paper were determined using AFM and Optical Microscope; the radiated paper, especially banana paper, showed a more suitable and stable surface than the non-radiated paper.

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