Fabrication of magnetic sugarcane bagasse paper

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Abstract. Generally, development in the pulp and paper industry requires extensive cutting of trees, which in effect contributes to deforestation. The dramatic growth in demand for wood supply, combined with the increasingly increasing cost of timber, has created a surge of interest in the use of non-wood plant fibres for paper production in widely developed countries. The use of waste material in pulping and paper-based industries could be beneficial as it helps prevent the need for disposal, which currently increases agricultural costs and causes environmental deterioration due to pollution and fires. In this research, the sugarcane bagasse was dry and chopped into 5 cm in lengths. The fibre and pulp were separated and put in a pulp disintegrator then it was weighed and mixed with water. The paper that fabricates will be irradiated with gamma-ray and then followed by characterizing with Scanning Electron Microscope- Energy Dispersive X-Ray Analysis (SEM-EDX) and Fourier-transform infrared spectroscopy (FTIR). The SEM-EDX result shows that the weight and atomic percentage of the ferrite (Fe) increase after the irradiation. While for the FTIR, the entire sample exhibit the absorption range of 3400 to 2400 cm⁻¹ region. The paper will be compared with the properties of multipurpose paper.

1. Introduction
Bagasse is the remaining residue of the fibrous after the crash of the sugarcane to extract its juice. Sugarcane bagasse among the most essential raw materials for paper and pulp manufacturing in other regions. The benefit of reducing deforestation will be introduced by using crop residues instead of wood. As bagasse is produced of non-wood fibre, therefore, it can be used as a substitute in replacing non-wood fibre as a sustainable source.

Sugarcane bagasse is an abundant lignocellulosic waste usually cultivated in open sugarcane processing countries. The sugar cane stalk includes two parts, the inner pit usually contains utmost sucrose and the outer rind containing lignocellulosic fibres. Throughout sugar processing, the sugar cane stalk is shredded in the process of extracting sucrose. This method generates a significant quantity of sugarcane bagasse residue which includes both pith fibres and crushed rind [1].

Besides that, the sugarcane residue after sugar cane extraction is one of the most widely available lignocellulosic fibre papermaking resources in certain developing countries. Approximately 54 million tons of bagasse are generated annually. These crop residues provide a plentiful, affordable, and widely accessible supply of sustainable lignocellulosic biomass. The chemical compositions of pure bagasse fibres bundles are cellulose, lignin, hemicelluloses, ash, and ethanol/dichloromethane extract.
Next, the addition of other material to paper processing became very necessary to significantly raise the efficiency of paper output. The filler usage in final chemistry and paper preservation help needs a certain degree of comprehension in the area of paper output chemistry. It can contribute to improved paper composition and, if used throughout the paper production process, maintain as much as the filler. For more than two decades, a filler is being used as an addition to enhance the consistency of material, such as clarity, stiffness, smoothness, and durability, also the manufacturing costs [2].

Bacteria and fungi may reduce or weaken the feature of the fibre in the sugarcane bagasse, which may lead to a significant presence of a spot or a stain in the paper. Simultaneously, the credibility of the paper will be affected since it is harmful to be used [3].

In a previous study, sugarcane bagasse has been exposed to gamma irradiation in various doses to know the changes in the characteristics for chemical, structural, physical, morphological, and properties of that sample itself. Demand to produce an eco-friendly, and cost-effective, the addition exposure was found effective in strengthening the digestibility of the lignocellulosic of the sugarcane bagasse [4].

It is believed that the non-wood option has a fibre quality equal to that of traditional wood products. This research offers useful knowledge on the implementation of non-wood raw materials to be used in the industry of paper in Malaysia. Besides, those non-wood fibres have a wide range of exceptional physical and optical features that might be leveraged to improve the quality of the product. As a result, it will ensure the sustainable utilization of natural resources.

2. Methodology

Sugarcane bagasse was sorting from dust and sand, by crushing, washed, filtering and air-dried to approximately 15% moisture content conducted prior to pulping. The pith was removed by around 30 percent. The sugarcane bagasse was dry depithed, crushed and chopped to about 5 cm length. The sugarcane bagasse fibre was stored in an oven for 2 hours. After the pulp was separated from the fibre. It was transferred for the drying process. The process took about 5 to 10 minutes to ensure the pulp is dry before transferring it. The sugarcane bagasse pulp was undergoing a blended process until it becomes fine pulp about 5 minutes. After that, the pulp was crushed in the machine until it becomes a small lump of pulp. Then the pulps and ferrite magnet were weighed 20g and 7.5g each samples respectively using weighing balance before mixed with standard pulp disintegrator. The magnetics sugarcane bagasse pulp was blended with 2 liters of water in a Standard pulp disintegrator Model UEC-2008. In aqueous suspension, a known amount of pulp is drained through the screen plate of standardized slits to detach the fibre and the degradation is dependent on the disparity in size between them. This process is to know the smoothness of flow and disintegration of the pulp. A 12 liters of water was added to the solution of pulp in the vessel when the compressor was on. This machine of the drainage system generates a consistent flow through the whole wire, thereby making extremely uniform sheets. After the drainage process, the pulp that was embedded with the filler which is a ferrite magnet then was collected for about 1 liter.

The paper was created when the water was pumped out and leave the paper on top of it. Magnetics sugarcane paper was compressed with a rapid sheet drying machine. This method is used to reduce the drying time of wet pulp or paper samples. Flat heating elements are required for it. Magnetics sugarcane bagasse was prepared. The paper was cut into 5cm × 5cm to radiate in gamma cell irradiator. This is because, the lower the surface area, the higher the radiation can focus on the magnetic paper and the ionizing radiation particle. The properties, surface, structure of the magnetic paper was observed pre- and post-radiation to identify and observe the changes in the paper.

3. Results and discussion

3.1 Characterization with Scanning Electron Microscope- Energy Dispersive X-Ray Analysis (SEM-EDX)

The morphology of irradiated sugarcane bagasse as shown in Figure 1(a) clearly showed the shape of the microcrystalline cellulose structure of the bagasse. These shapes of cellulose in the lignocellulosic structure have appeared. The presence of these shapes of cellulose in the sugarcane bagasse paper indicate the
complex structure in the components of it. Figures 1(a) shows the SEM images of the irradiated magnetics sugarcane bagasse paper. On the surface of it, exists as there is a net morphological, perhaps due to reaction between chemicals used. EDX analysis showed low presences of Fe in this fraction Figure 1(b). EDX spectrum Figure 1(b) also shows high Fe content which is 5.96% weight and 1.52% the atomic percentage of the Fe.

Figure 1. The SEM surface morphology micrograph of sugarcane bagasse fibre (a) surface morphology, (b) The EDX pattern of bonding between the magnetic particle in the lumen of the fibre for soda process technique.

Figure 2(a) shows the micrograph of multipurpose paper. From the image (white round shape) it can be seen that the fibre has uniform, smooth, and homogenous surface. EDX analysis showed no presences of Fe in this fraction as there is no ferrite used in this particular sample. EDX spectrum Figure 2(b) also shows no presence of Fe content in weight and the atomic percentage. This is due to no element of ferrite magnet that is associated with this multipurpose paper.

Figure 2. The SEM surface morphology micrograph of sugarcane bagasse fibre (a) surface morphology (b) The EDX pattern of bonding between the particle presents in the multipurpose paper.

Figure 3(a) represents the compact structure of sugarcane bagasse fibre. The micrograph shows the deconstruction of the compact rigid structure into cellulose fibres that appeared in irregular uniform strips reveals as a loosen bundles. EDX analysis showed average presences of Fe in this fraction Figure 3(b). The EDX spectrum Figure 3(b) also shows high Fe content which is 12.30% weight and 3.33% the atomic percentage of the Fe.

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Figure 3. The SEM surface morphology micrograph of sugarcane bagasse fibre  (a) surface morphology  (b) The EDX pattern of bonding between the magnetic particle in the lumen of the fibre for soda process technique.

Among SEM images of irradiated magnetics sugarcane bagasse paper, the structural occur molecule agglomeration. During devolatilization, volatile matter is trapped on the surface of the particles and allows the surface to bubble initially, altering the shape of the particle and gradually bubbling out of the surface and altering the surface of the particles. Due to the low melting compound, breaking chemical bonds and melting certain compounds can cause fibre structures to separate from the original material and cause the particle to shrink in size and lead to fragmentation followed by particle agglomeration.

The EDX spectrum Figure 4 (b) shows no presences of Fe content in weight and the atomic percentage. This is due to no element of ferrite magnet that is associated with this multipurpose paper. Besides that, the presences of aluminium (Al) due to non-organic materials in it. Paper also contains nonorganic materials to improve its properties. For instance, chalk (CaCO₃) and kaolin clay (Al₂Si₂O₅(OH)). Also, titanium oxide (TiO₂) is also commonly used in paper for bleaching it. This multipurpose paper may be use bleaching during the process of papermaking.

Figure 4. The SEM surface morphology micrograph of sugarcane bagasse fibre  (a) surface morphology  (b) The EDX pattern of bonding between the particle presents in the multipurpose paper.

Knowledge about fibre width or length important for comparing various kinds of wood and natural fibres. In cellulose based fibres, a high aspect ratio (width or length) is very important as it gives an indicator of potential strength properties. So, differences in fibre morphology may be attributed to variations in physical properties. Major differences in structure such as density, cell wall thickness, length and diameter do result in differences in physical properties. Large structural variations, such as thickness of the cell wall, length, diameter, and density may account to a result in differences in physical properties.
Elementary sugarcane bagasse fibre wall possesses a unique multilayer configuration called polylamellate structure, where every layer is reinforced with cellulose microfibrils at different angles. The microscopic structures of the sugarcane bagasse fibres are cellulose, hemicellulose, lignin and pectin. This structure determines the mechanical properties of the technical fibers and commit to the modulus and strength of the sugarcane bagasse culm.

To summarize, most of sugarcane bagasse fibre samples presented in figures above indicated that the fibers are agglomerated. It was separated from the polymer matrix and appeared to be free of any matrix interactions as well as very visible cracks and voids. Weak interfacial stability between hydrophobic polyolefins and hydrophilic cellulosic fibres was the cause from the absence of any physical interaction between the fibres and the polymer matrix.

On the other hand, the usual sugarcane bagasse fibre showed and exhibited strong interfacial adhesion as the fibers adhere better to the surfaces of the polymer matrix. This is may be due to radiation technique that cause the changes of surface morphology in the magnetics sugarcane bagasse paper.

3.2 Characterization with Fourier-transform infrared spectroscopy (FTIR)

Figure 5(a) illustrates the vibration peaks at 3335.88, 1315.88, 1029.45, 558.87 and 435.74 cm\(^{-1}\). The presence of these vibrations peaks indicates the formation of matrix generating in the lignin that is associate with cellulose and hemicellulose. This spectrum also assigned to alcohol group respectively.

Next, figure 5(b) shows the spectrum of multipurpose paper. The spectrum of this sample shows absorption bands at 3334.69, 1316.01, 1160.19, 1027.74, 558.71 and 435.39 cm\(^{-1}\). While the peak at 3334.69 cm\(^{-1}\), 1160.19 cm\(^{-1}\), and 1027.74 cm\(^{-1}\) correspond to O–H linked shearing (polysaccharides), C–O–C asymmetrical stretching (cellulose) and C–O stretching respectively. Figure 4.8(b) which is a modern magnetics sugarcane bagasse paper. The spectrum at 1.0 kGy dose spectrum exhibits the vibration peaks at 3332.64 and 2893.31 cm\(^{-1}\) correspond to O–H linked shearing (polysaccharides) and C–H symmetrical stretching (polysaccharides) respectively. The results of the characterization in Figure 6 show the entire sample exhibit the absorption range of 3400 to 2400 cm\(^{-1}\) region which shows the characteristics for stretching vibration of O-H and C-H bonds.

To summarize, the spectra of samples in Figure 5 and 6 represent absorption bands of magnetic particles and fibers. This indicates an effective interaction between ferrite nanoparticles and the cellulose network of fibers. The magnetic properties may exhibit ferromagnetic behaviour as shown by magnetization [5].

Figure 5. Graph of FTIR spectra of non-irradiated magnetics sugarcane bagasse paper (a) soda process (b) multipurpose paper.
Figure 6. Graph of FTIR spectra of irradiated magnetics sugarcane bagasse paper with different doses of radiation which are 0.5kGy, 1.0kGy, 1.5kGy, 2.0kGy, and 2.5kGy (a) soda process (b) multipurpose paper.

Figure 7 shows the water absorbency time for the different types of papers produced from magnetics sugarcane bagasse paper and multipurpose paper. The absorbency of magnetics sugarcane bagasse paper is quite lower than that of multipurpose paper. Its means magnetics sugarcane bagasse paper fibre can be used for packaging, printing and wrapping paper etc. By compared magnetics sugarcane bagasse paper and multipurpose paper, magnetics sugarcane bagasse paper lower absorbency than multipurpose paper [6].

The absorben ccy will influence the mechanical and surface properties of paper created which shows less dimensional dependability contrary to what would be expected. The quality paper needs generally excellent dimensional stability contrary to what would be expected because the structure and the quality of the paper rely upon it. Cellulose fibre can expand from 15 to 20 % from dry condition to immersion where it can cause the change is solidness. Such a change in measurement will make the dimensional stability decline cause undesirable cockling and twisting in the dimensional strength of the paper.

Figure 7. Graph of percentage of water absorbency between magnetics sugarcane bagasse paper and multipurpose paper.

Figure 8 shows the pH reading between non-irradiated magnetics sugarcane bagasse and multipurpose paper. If we look at the trend of pH over time, we can see that uptake soda process technique by using machine and technology are more alkaline than others. According to [7], at this point, when the pH rises as high as pH 7~10. This may due to the loss of the impurities that exist on the surface of the fibre. This can be clarified that the properties of magnetics sugarcane bagasse paper were similar with commercial paper.
The pH reading which is alkaline was due to the properties of the pulp itself and makes this magnetic sugarcane bagasse paper suitable as a substitution as paper.

Figure 8. Graph of the pH reading between non-irradiated magnetics sugarcane bagasse paper technique with multipurpose paper.

Figure 9 illustrates the results of post-irradiation magnetics sugarcane bagasse paper with multipurpose paper. A graphical graph to interprets more about the pH reading. By comparing the pH value between irradiated magnetic sugarcane bagasse paper with multipurpose paper, their pH value is more than multipurpose paper. This can be clarified that magnetics sugarcane bagasse paper are alkaline and similar to multipurpose paper. Also, magnetics sugarcane bagasse paper can be potentially considered suitable as a substitution for paper.

Figure 9. Graph of the pH reading between irradiated magnetics sugarcane bagasse paper and multipurpose paper

4. Conclusion

Without a doubt, the introduction of filler in this study alter the properties such as texture, strength, and opacity. Thus, ferrite (Fe) magnet as a filler enhance the paper physically as ferrite is a hard-magnetic material with distinct properties such as good mechanical hardness and chemical stability, thereby it is a convenient material for magnetic paper production. The physical changes of the paper may be attributed to thermal, structural or morphological of the fibre after the fibre treatment or irradiation process.
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