Investigation on Physical Properties of Magnetic Pineapple Leaves Paper- Preliminary Study

**ORIGINAL ARTICLE**

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**Abstract.** High paper production demand can cause a year-over-year increase in deforestation. This increased deforestation could increase environmental issues like flash flooding and global warming. This negative effect is unsuitable for the environment, particularly for humans and other habitats that need this forest resource. Therefore, replacing wood with non-wood fibres should be considered a substitute for paper making without cutting more trees. Non-wood fibre production is environmentally friendly and significantly impacts forest growth and conservation. Pineapple leaves have a substantial fibre structure suitable for paper making. Pineapple leaves contain higher cellulose than wood fibre, making them a good substitute for paper making, and they have a lower content of lignin that can increase the paper's strength. In this study, introducing radiation on paper will also enhance the quality of pulp production, especially in preventing fungi on paper. This is commonly used in food wrapping or packaging, and cleanliness is the most crucial aspect that should be considered to avoid food damage. In this study, irradiated magnetic pineapple leaf paper shows better structure and effect than non-irradiated paper. This is because the radiation changed the properties of the paper.

**Keywords:** Pineapple, paper, absorbance, pulp, radiation

1. Introduction

Eco-friendly paper production is an alkaline and non-polluting process that has many advantages over conventional methods, such as it has a low density and eco-friendly nature besides continuous supply, easy and safe handling and saving our mother earth from global warming [1]. Pineapple leaf fibre also has higher cellulose content, which is durable for paper-making production. Because of the higher cellulose content, pineapple paper was an excellent alternative to replace wood fibre. Pineapple or Ananas Comosus, the scientific name, is a typical tropical plant consisting of coalesced berries. It consists of cellulose, holocelluloses, hemicelluloses, and lignin with certain extractives like gum and resin [2]. As pineapple leaves fibre in non-wood fibre, there can be alternative ways to replace non-wood fibre as a renewable material.

This will lead to better paper formation and retain as much filler as possible if used during paper making. For over two centuries, filler has been used as an additive to improve the quality of paper, such as brightness, opacity, smoothness and printability, while reducing production costs [3].Paper is usually made of wood from forest resources. Paper production was highly demanded, and 90% of the wood was used in the world for the production of pulp and paper [4]. As a result, large areas of forest destroyed by more trees need to be cut to meet the needs of the wood fibre industry, mainly used for educational, packaging and cleaning purposes [5].

Pineapple leaf fibre (PALF) is one of the most widely grown waste materials in both Malaysia and Asia in the agricultural sector. Pineapple leaves have a higher cellulose content, which might be a suggestion as a new substitution for paper instead of using wood fibre. Pineapple fruit is significant commercially, and leaves are considered fruit waste materials used to produce natural fibres [1]. At the same time, the introduction of filler in the production of paper might be necessary to improve the quality and the characteristics of the paper.

The decreasing activity of deforestation is now causing the price of wood to rise rapidly. As the primary basis for producing paper is this shortage of wood resources, the alternative should be considered as a substitute for timber in paper production [6]. The possibility of the presence of fungi is increased in paper production. The fungi can cause spots or stains on paper and affect paper's integrity by degrading their cellulose fibres. This presence of fungi could affect health and the risk of disinfection. To avoid this risk and infection, radiation on paper and book production can be taken differently [7].

This study's significance is exposing others to new inventions of making pulp for paper by using another source, such as wood. The production of pineapple leaf paper will help decrease deforestation by making paper using wood. Still, it will introduce biodegradable, biocompatible and eco-friendly paper production using non-wood material. This will help the industry implement clean technologies to create a new economic and environmental order. Meanwhile, magnetic material inside the paper acts as a filler that will improve the quality and strength of the paper.

This study will also give many benefits, especially to paper industries, to create paper from pineapple leaves that will provide alternative ways to reduce environmental problems and be cost-effective. This is because pineapple leaves are easy to get, and the harvesting period of the pineapple is short. Besides, the steps for producing pineapple leaf paper are more straightforward, simple, and cost-effective than wood fibre paper.

**2. Literature Review**

*2.1 Pineapple Leaves as Paper*

Paper is commonly produced from cellulosic fibres and has some specialised functions used for educational, packaging, and cleaning purposes. Nowadays, paper consists mainly of wood, the primary raw material used in producing global pulp and paper. This phenomenon can contribute to the depletion of forest resources that have an adverse environmental impact [5].

The pineapple plant is known as "Ananas comosus," a herb with a height of 0.75 to 1.5 m and a spread of 0.9 to 1.2 m, according to [5]. It also has long, pointed leaves with sharp spines on 50 to 180 cm long edges. The pineapple plant takes 12 to 14 months to flower, depending on the variety, and about 6 to 8 months to mature the fruit and consists of about 30-50 leaves with an average weight of 35 g per leaf, resulting in approximately 1-1.5 kg of leaves per plant left in the field after cultivation.

In addition, pineapple cultivation covers more than 300 ha of land in Mauritius. The pineapple leaves sent to the landfill as waste could instead be used as a source of natural fibres for their actual value. Agro-waste material is abundant in Malaysia but has yet to be used for maximum production, particularly agro-waste materials such as pineapple leaves. After harvesting, most of the agro-waste material was razed. Most people do not know that pineapple leaves comprise cellulose, holocellulose, hemicellulose, and lignin, which are higher than cellulose in wood fibres. Based on this suggestion, non-wood species can also provide an excellent solution to the need for alternative fibres [2]. Table 1 shows the chemical composition of pineapple leaf fibre that can be used for paper making.

**Table 1.** Chemical composition of pineapple leaves the fibre [9]

|  |  |
| --- | --- |
| Chemical Composition (%) | Source from the Journal |
| [9] | [10] | [11] |
| Cellulose | 56 – 62 | 70 – 82 | - |
| Hemicellulos | 16 – 19 | 5 – 12 | 9.45 |
| Hollocellulose | - | - | 87.56 |
| Alpha cellulose | - | - | 78.11 |
| Lignin | 9 – 13.0 | 5 – 12 | 4.78 |
| Pectin | 2.0 – 2.5  | - | - |
| Fat and wax | 4.7 | - | - |
| Ash | 2.0 – 3.0 | - | - |

*2.2 Magnetic Material in Paper Production*

In recent decades, the interest in lignocellulosic fibres has increased. It has good mechanical characteristics, low density, low cost and recyclability. The bio-organic nature of cellulose requires some change to improve the surface of its interfacial properties [10].

Furthermore, magnetic paper has attracted extensive attention due to its wide range of manufacturing, agriculture, security, and health applications. Unlike other magnetic materials, magnetic paper shows some superiority in properties such as softness, renewable use and resistance to folding. Magnetic paper is generally prepared by adding ferrite to the amorphous pulp fibre area. This preparation was ready through the lumen loading process or in situ synthesis. However, the uses of this ferrite, due to the deep colour of ferrite, could affect the colour of the paper, which usually shows low whiteness and even presents brown or black. This mainly occurred in white paper, where its application was restricted [11].

In addition, the introduction of filler particles into the lumen of the pulp fibres has advantages such as the filler being protected by the cell wall from dislodgement during paper making and the absence of the filler on the outer surface of the fibre resulting in better interfiber bonding and thus creating higher paper strength. Two stages of impregnation and washing were involved in the process. Papermaking involves colloidal materials such as fibre, filler and aid for retention. Papermaking chemistry is based on physical chemistry and colloidal chemistry. Therefore, understanding the chemistry of papermaking is essential if the papermaking system is to be controlled appropriately (Zakaria et al..

*2.3 Filler for Paper Production*

Incorporating fillers in paper has been a regular practice for a long time. Even though the term 'filler' is somewhat uncomplimentary, this group of predominately inorganic materials has become a fundamental part of numerous paper grades. The first reason for adding filler to the paper matrix was to lower furnish costs with the measure of filler constrained uniquely by quality considerations. Today, the principal requirement for fillers is to give explicit quality upgrades to the sheet. Depending on the performance attributes of the fillers and the amount added to the paper, these items can improve the completed sheet's optical, physical, and aesthetic properties. Today, using fillers depends on choosing materials that will provide both expense and quality enhancements.

The conversion to alkaline papermaking in North America has stressed this methodology, where fillers intended to increase the value of the paper are routinely utilised. This pattern has been affirmed by the fast development of the esteemed tonnage, including strength fillers obtained by paper mills [12]. The fundamental mineral fillers for acid paper are talc, hydrous kaolin, calcined kaolin, precipitated silicas and silicates (PSS) and titanium dioxide. Meanwhile, talc, hydrous kaolin, PSS, titanium dioxide, GCC, and PCC are utilised for neutral or alkaline paper [13].

Fillers are added to paper at different rates and percentages, generally 10-20%, to perform various capacities. The decision of which filler or mix of fillers to utilise relies on the desired properties. While fillers are used in a wide range of paper grades, they locate their most prominent utility in printing and writing grade papers, as shown in Table 2. Fillers can contribute the following properties to paper to improve sheet formation by filling the void regions around fibre intersections and providing a smoother surface. Plus, filler can increase opacity and brightness while providing enhanced printability for various reasons, for example, a softer, progressively uniform surface, less show-through brought about by increased opacity, and better ink receptivity, reducing ink penetration, wicking, and strike-through simultaneously filler can improve dimensional stability (most fillers are not hygroscopic like fibres) and give cost reserve funds by supplanting more excellent expense fibre with lower cost fillers [12].

**Table 2.** Paper grades, fibre composition, pigment and coating loading, and end uses [13]

|  |  |  |  |
| --- | --- | --- | --- |
| **Paper Grade** | **Fibre Raw Material** | **Pigments** | **End Uses** |
| Newsprint  | De-inked pulp and mechanical pulp | Filler loading up to 12% initially from de-inked pulp | Newspaper, inserts, flyers (advertising) |
| Especially newsprint such as books, paper and high-brightness | De-inked pulp and mechanical pulp | Filler loading <10%, mainly pigments, can be used as well | Newspaper supplements, newspapers, books, directories, advertising  |
| Supercalendered (SC) papers. SC B, A and A+ grades | Mechanical and chemical pulp | Filler loading up to 35%Filler loading up to 10%, coating 25% - 30% of paper weight | Multicolour magazines, catalogues, supplements, inserts, and advertising materials. Used in gravure and offset printing |
| Coated mechanical paper (also called machine-finished coated [MFC] paper | Mechanical and chemical pulp | Filler loading up to 10%, coating 20% - 35% of paper weight | Magazines, catalogues, supplements, books, advertising materials |
| Wood-free uncoated (WFC) papers | Chemical pulp | Filler loading up to 25% | Office papers, writing papers, envelopes, direct mail, magazines, books, advanced materials |
| Wood-free coated (WFC) paper, also coated fine paper (art printing paper) | Chemical pulp, possible to use some chemical-thermomechanical pulping (CTMP) | Filler loading up to 15% and double or triple-coating | Magazines, brochures, direct mail, annual reports, books, advertising materials, higher quality books, reports |
| Specially papers | Chemical pulp | Filler load and coating are dependent on grade | Label papers, label release papers, food wrapping, packaging |
| Kraft papers | Chemical pulp | No pigments | Sacks, bags, wrapping and packing, envelopes |

*2.4 Future of Non-Wood Material as Paper*

In Europe, the paper industry has become aware of this issue, and paper recycling is now one of its activities. The European reuse rate was 72.5% in 2016, according to the Confederation of European Paper Industries (CEPI). This showed that paper recycling had brought significant life benefits, particularly environmental ones [14].

Wood contributes approximately 90% of the world's conventional raw material in pulp and paper production. To obtain wood, the reduction of forest supplies impacted the environment and human beings. Alternatively, the use of wood fibres in paper production must be avoided [2]. The use of non-timber or non-wood assets as an element for paper creation covers 10% of its use worldwide. This circumstance contrasts with the nation's indications and the nation's reliance. For example, China uses more crude material for paper production than wheat straw and other non-wood filaments. Interest in a paper increases with the current in today's progressively mechanical progression. Testing the findings of the assumption that advancing data innovation will prompt less paper and network utilisation to make a paperless world. In this context, numerous choices have been made to replace the essential wood wells in the pulp and paper industries [6].

In addition to forest protection, using non-wood plants as raw material may be notable for reusing reeds, wheat straw or pineapple leaves. Non-wood pulp and paper made with reed or wheat straw as raw materials comprise a considerable portion of the industry in developing countries such as China and India [9]. Thus, non-wood plants offer several benefits, including short growth cycles, modest irrigation and fertilisation demand, and low lignin content, which reduce energy and pulping chemicals. The paper industry possibly has an abundance of non-wood fibres. Since all these plant materials contain cellulose in the form of fibres, they are potential sources of pulp with a lower threat to environmental degradation than wood, which is traditionally the most widely used lignocellulosic material in the production of various types of pulp, furniture and boards, as well as a source of energy [2].

*2.5 Gamma Radiation Treatment for Microbe Removal in Paper Production*

Paper production is commonly made from wood pulp, which may limit the production of the paper due to a decrease in the wood source. Therefore, overcoming this lack of sources and finding alternative sources to improve paper production quality is essential. In addition to seeing other paper production resources, there is a need to increase the paper's lifespan to withstand the presence of bacteria and fungi.

The integrity of bundling materials, such as paper generation, is fundamental to maintaining the aseptic condition. The assessment of bundling materials is vital for a safety application and the security utilisation of radiation for human services item sanitisation [15].

Besides, microorganisms and pests may also degrade the paper's cellulose fibres, affecting their integrity. This damage can be caused by the chemicals produced by the processes of metabolic fungi while using cellulose as a source of nutrients and pigmenting mycelium and spores. The fungi that catalysed the cellulose hydrolysis could then produce the enzymes. These pillows and bacteria in the paper also pose a health risk that may affect disinfection (Coppola et al.. Gamma rays look at alpha and beta with higher penetrating power. In particular, as with other disinfectant treatments, irradiation has the preferred point of view that it does not leave unsafe buildings on the material handled [16].

*2.6 Structure, Mechanical and Physical Properties of Magnetic Paper*

Paper is generally commercialised according to its grammage and mass per unit area. Consequently, these paper properties play a significant role in regulating the price of paper for both the producer and the consumer. Depending on the end of the paper, the grammage of the paper can be varied by increasing or decreasing the amount of pulp used for a sheet. Several physical properties also depend on grammar, such as thickness and bulk density, and growing grammar will undoubtedly increase the paper's mechanical and physical properties [5].

Rather than by and significant considering the grammage of the paper, the crude material utilised, for example, the pineapple leaves generation, is vital to decide the mechanical properties of the cellulose structure of the pineapple leaves paper. The chemical treatment completed on these specialised strands, while improving their fineness, degraded their tensile properties. The tensile properties of fibres obtained from the pineapple leaves were found to have the most tensile rigidity and middle-of-the-road prolongation at the break [19].

With the expansion of the magnetic molecule, the attractive properties are firmly identified. Past investigations recommend that under harmonious conditions, ferrite magnet structures create carious hurdles by building hydroxylated buildings, and their arrangement is very pH-subordinate. Past research also shows that precipitation occurs at a pH over 6 [18].

Paper was the more radiation-touchy among the materials considered, and the effects of radiation were gradually articulated with brightness, pH, tearing resistance, bursting strength and elasticity. No pinhole was incited by radiation concerning plastic film, and the impact on elasticity was not critical. Even though the seal quality bundling (pouches) decreased by increasing dose, the stability of the fixing was protected [19].

**3. Materials**

Pineapple leaves and pure ferrite magnets have produced magnetic pineapple leaf paper. Besides using pineapple leaves and a ferrite magnet, another material used in this experiment was Sodium Hydroxide, which was used to soften the pineapple leaves before proceeding to the next step of the preparation. For radiation of the magnetic pineapple leaves paper, Cobalt-60 Gammacell 220 Source, series no.142 is used to radiate the paper because gamma radiation has a higher power of penetration through paper instead of using alpha and beta radiation, which have lower power of penetration. This gamma radiation needs to be used in different doses to show the various effects on the paper, and the result of the experiment can be compared.

**4. Methdology**

*4.1 Preparation of pineapple leaves pulp*

Pineapple leaves were collected after the fruit was harvested to make pineapple leaves paper. The pineapple leaves were separated from their bundle and washed thoroughly with distilled water to remove dirt and soil particles. To avoid injuries while handling the pineapple leaves, the spiky edges were cut, and the leaves were then allowed to dry in an oven at 90 °C for 180 minutes. Then, the pineapple leaves were cut into 5 cm long in size. After that, the leaves were soaked in 10%-15% Sodium Hydroxide (NaOH) solution at 100°c for another 45 minutes to soften the leaves. Rinse the leaves from excess NaOH solution with distilled water and blend the leaves for about 7-10 minutes to get the fine pulp produced from the leaves.

*4.2 Preparation of Magnetic Pineapple Leaves Paper*

After the pulp was prepared, the magnetic material, ferrite magnet powder (was put into the pulp prepared; this process was called the lumen-loading process. Filler suspensions were prepared by dispersing 7.5 g of magnetic pigment Fe3O4 in 250 ml of distilled water with a laboratory mechanical stirrer. Then, 15 g of pineapple leaf pulp was disintegrated in a tub of 1250 ml of distilled water in a separate container. The disintegration then left for about 30 minutes in another mechanical stirrer operating at a standard rotor speed of 1000 rpm.

After 30 minutes, the suspension filled with magnetic pigment Fe3O4 was poured into the tub containing the pulp. Then, stirred for another 30-60 minutes at the standard rotor speed of 1000 rpm. During this process, the magnetic pigment entered the lumen of the fibres and became attached to the surface [3].

The composition of pineapple leaves pulp and ferrite magnet undergoes lumen loading process then poured in the mold and movable part called deckle. After that, the mold was removed from the tub to let the excess drains completely. The dry clothes were used to ensure it ultimately drained, then the paper dried under the sun after the mould was removed and waited to dry for 2-3 days, then the sample was pressed with an electric hot iron to improve the smoothness of the paper. The magnetic pineapple leaves were ready to use.

*4.3 Preparation of Irradiation on Magnetic Pineapple Leaves Paper*

In this experiment, Cobalt-60 Gammacell 220 sources were used as a source to radiate the magnetic pineapple leaves paper. The use of this gamma radiation rather than other radiation like alpha or beta radiation is because alpha radiation has lower penetration energy, significantly penetrating through paper. At the same time, beta radiation is also low enough to lower the presence of fungi.

The irradiation is reformed in the Faculty of Science and Technology, Universiti Kebangsaan Malaysia (UKM). Firstly, the paper was cut into 4 cm x 4 cm to radiate in a gamma cell irradiator, as shown in Figure 3.5. This is because the lower the surface area, the higher the radiation can focus on the magnetic paper and the ionising radiation particle. The magnetic paper's properties, surface, and structure were observed pre and post-radiation to identify and observe the changes on the paper. Then, the sample was put into a Cobalt-60 Gammacell 220 radiation machine.

**5. Results and Discussion***5.1 Comparison by Tearing Tester Machine*

The tearing tester machine was used to measure the force required to continue tearing an initial cut in sheet materials. Table 3 shows the differences between magnetic pineapple leaf paper and multipurpose paper.

Table 3: Differences between the tearing of Magnetic Pineapple Leaves Paper and Multipurpose Paper.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Type of paper** | **Sample** | **Tear Gap (gf)** | **Tear Angle(°)** | **Tear Strength (N)** | **Tear Index gf.m2lg** | **Tear Ratio gf. m2lg** |
| Magnetic pineapple leaves paper | 1 | 3200.00 | 132.80 | 130.154 | 0.260 | 26.03 |
| 2 | 3200.00 | 133.25 | 89.485 | 0.179 | 17.90 |
| 3 | 3200.00 | 133.40 | 75.441 | 0.151 | 15.09 |
| Multipurpose paper | 4 | 3200.00 | 133.55 | 61.364 | 0.123 | 12.27 |
| 5 | 3200.00 | 133.35 | 59.365 | 0.117 | 11.73 |
| 6 | 3200.00 | 133.20 | 56.665 | 0.113 | 11.33 |

**Figure 1.** Graph of tear angle (°) versus tear strength (N) for magnetics pineapple leaves paper.



**Figure 2.** Graph of tear angle (°) versus tear strength (N) for multipurpose paper.

Three samples of each magnetic pineapple leaf paper and multipurpose paper were analysed using the tearing tester machine. The mechanical properties of Figure 1 and Figure 2 show that magnetic pineapple leaf paper has a higher tear angle and tear strength compared with multipurpose paper. This is due to the addition of filler in the magnetic pineapple leaves paper, which gave more strength to the structure of the paper. Combining the pineapple leaves pulp and ferrite magnet produced the most stress-resistant paper and indicated higher bonding strength during paper production, making the paper more robust and suitable for packaging purposes.

*5.2 Comparison between Absorbency of Magnetics Pineapple Leaves Paper and Multipurpose Paper*

The water absorbency of a material also has a strong influence on printability. Table 3 and Figure 3 show the water absorbency time for the different types of papers produced from magnetic pineapple leaves and multipurpose paper. The absorbency of magnetic pineapple leaves paper is relatively lower than that of multipurpose paper. This means that magnetic pineapple leaves paper fibre can be used for packaging, printing, and wrapping paper [20].

The absorbency will influence the paper's mechanical and surface properties, which shows a less dimensional dependability contrary to what would be expected. Quality paper generally needs excellent dimensional stability contrary to what would be expected because its structure and quality rely upon it. Cellulose fibre can expand from 15 to 20% from dry conditions to immersion, where it can cause a change in solidness. Such change in measurement will make the dimensional stability decline causing undesirable cockling and twisting in the dimensional strength of the paper [2].

**Table 3.** Percentage of water absorbency between magnetics pineapple leaves paper and multipurpose paper.

|  |  |
| --- | --- |
| **Samples** | **Absorbency (%)** |
| **15 min** | **30 min** | **45 min** | **60 min** | **75 min** |
| Irradiated Magnetic Pineapple Leaves Paper | 39.2258 | 41.1985 | 43.0472 | 43.3554 | 50.3950 |
| Multipurpose paper | 48.7640 | 51.7970 | 52.5988 | 56.4885 | 60.1399 |

**Figure 3.** Graph of % Absorbency against Time Taken (min)

**6. Conclusions**

Magnetics pineapple leaves paper was produced using environmental products, and the paper was irradiated to study the effect on the paper. The mechanical properties of magnetic pineapple leaf paper were determined using a taring tester machine. The result shows that magnetic pineapple leaves have higher tear strength than multipurpose paper, with 130.154 N being the highest for magnetic pineapple leaves paper and 61.364 N for multipurpose paper. By comparing magnetic pineapple leaf paper and multipurpose paper, magnetic pineapple leaf paper had lower absorbency than multipurpose paper.

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