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Investigation and Properties of Waste Banana Peel Composite for Paper Making Consist of Egg Shell

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ABSTRACT

Banana peels also include a range of starch and non-starchy chemicals, including cellulose, hemicellulose, lignin, pectin, and several other organic molecules. The banana peel's makeup is mostly made up of these non-starchy ingredients. Plant cell walls are structurally supported by the complex polysaccharide's cellulose and hemicellulose. Lignin is a sophisticated polymer that gives plant tissues stiffness. A form of carbohydrate called pectin has qualities that let it gel and function as a natural glue. The paper making continued growth with a new combination for reducing the cost of paper. The study of the waste box (WB), waste banana peel (WBP), and eggshells as a filler is tested for paper making using a pneumatic sheet press machine for 3 minutes. This paper was dried under the sunlight or iron until it was dried properly. The qualities for paper production are demonstrated by using varied grams of each paper throughout the combination paper-producing process and evaluating the physical and mechanical properties of paper made from different combinations. The evaluation involved the waste box and waste banana peel composite consisting of eggshells with a tensile strength test, tear test, and physical testing using a microscope, as well as determining starch and non-starch with iodine solution as testing.

Keywords: Banana peels; cellulose; hemicellulose; egg shell; non-starch; paper

1. Introduction

A significant by-product of agricultural waste product is banana peel. Researchers have previously concentrated their investigation on the use of waste banana peel as fibre reinforcement in the polymer matrix. Banana peel powder was used as the fibre or filler material to create a brake pad. The outcomes demonstrated that the composite brake pads' relative compressive strength was sufficient to withstand load application. It was determined that banana peel powder could be used as filler materials for large-scale manufacturing of asbestos-free brake pads without any negative effects, even though wear and morphological tests were not conducted to anticipate its wear resistance.

Discrete phases of composite resins are referred to as fillers. A filler can improve the strength and other qualities required for a restorative material. Fillers may be more resistant to hydrolytic breakdown if they are coated in silane. Organic fillers, like eggshells, are biodegradable and derived from sources that are renewable, allaying worries about

their disposal issues. Banana peel composite and eggshells may be compatible with the paper matrix to variable degrees. It is critical to achieve a strong binding and uniform dispersion between the fillers and the paper fibres to improve paper strength, printability, and other mechanical properties. However, compatibility issues can lead to poor bonding, reduced paper strength, and degraded paper quality. Thus, the inclusion of eggshells as fillers to the waste banana peel composite can have a considerable impact on several paper qualities, such as tensile strength, brightness, opacity, and smoothness. The ideal filler loading, composition, and processing conditions must be identified to achieve the necessary balance of these qualities while incorporating the composite fillers [1]. The chemical procedures used in pulping and bleaching can lead to water contamination and greenhouse gas emissions. Choosing alternatives reduces the environmental impact, supporting cleaner and more sustainable paper production [2]. Recycling paper and utilising alternative fibres can help reduce waste generated during the papermaking process. This is consistent with the concepts of a circular economy, which focuses on reusing and recycling products to reduce waste.

1.1 Waste Banana Peel for Paper Making

The banana peel fibres are combined with water to make a paper, either by themselves or in conjunction with other fibres. Then, using either a papermaking machine or more traditional methods like hand sheets, this paper is shaped into paper sheets. To create the finished paper product, several processing steps are completed, including sheet creation, pressing, and drying. Banana peel fibres can give paper special qualities that make it stand out from the competition. These might include the potential for natural colour fluctuations, increased surface roughness, and improved ink absorbency. The proportion of banana peel fibres used, the manufacturing environment, and the intended use of the paper will all affect the specific qualities.

It was discovered that paper made from banana peels has many more benefits than typical wood-based paper. According to previous research, banana peel paper has greater fibre due to its parchment. It is also three times more durable than typical wood paper and contains more cellulose and less lignin. Banana peels are also simple to come by, and banana trees develop more quickly [3]. As a result, a million tonnes of banana peels may produce 100,000 tonnes of paper, offering us additional simple ways to obtain resources for creating paper. Additionally, it has fire and water resistance, which increases its durability and makes it ideal for handling tasks like packaging.

1.2 Eggshell Powder as Filler in Starch Banana Peel Matrix for Paper-Making

Eggshells do not go through a particular chemical process that significantly changes their composition when they are employed as filler in papermaking. The eggshell particles, on the other hand, largely serve as physical fillers, adding to the paper's bulk and enhancing some qualities. The interaction of the fibres and other pulp constituents, as well as the bonding and drying processes, are the primary chemical reactions in the production of paper. However, calcium carbonate (CaCO3), a chemical molecule, is the major component of eggshells [4]. The calcium carbonate in eggshells may interact with other substances in the pulp during the papermaking process, such as sizing agents or paper additives. When using acid-based sizing agents, for instance, the calcium carbonate in the eggshells can neutralise the acid and produce calcium salts and water as a by-product. This reaction can assist in lowering the acidity and regulating the pH of the paper. Calcium carbonate can also function as a buffering agent due to its alkaline nature, which contributes to the pH stability of the papermaking system. The eggshell consists of 2% protein and 2% carbohydrate content [5]. Recently, the paper industry has found success using proteins and carbohydrates as additives to increase paper strength and filler retention. The authors of the current work were inspired by all these facts to develop eggshells as a novel filler for the paper industry.

2. Materials and Methods

The paper-making from agricultural waste was done by using the waste box (WB), waste banana peel (WBP) and eggshell as a filler with 45 microns. The banana peel waste is the main ingredient, and eggshells are the secondary ingredient. Waste boxes, eggshell powder, banana skin powder, beakers, stainless steel spoons, distilled water, hot string plates, and measuring cylinders are the items. Small-to-medium-sized businesses (SMI) gathered eggshells and banana skin, while other organisations collected eggshells and banana peels. Eggshell was cleaned, dried, and powdered, while banana peels were dried in an oven for 24 hours to remove moisture content [6]. The average particle size of eggshell powder after being filtered using a sieve was 65 m.

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Waste banana peels (*Musa paradisiac* L.), eggshells, and a recycle box were selected for this project for paper making. Waste banana peels were collected in the nearest area in-store, Kg Jedok. Meanwhile, the recycle box was collected near campus, and eggshells were collected at the food store. The waste materials, as shown in Fig. 1, which were collected from eggshells, waste banana peels, and recycle boxes, were dried in an oven at 60° of temperature for 48 hours using a laboratory oven.

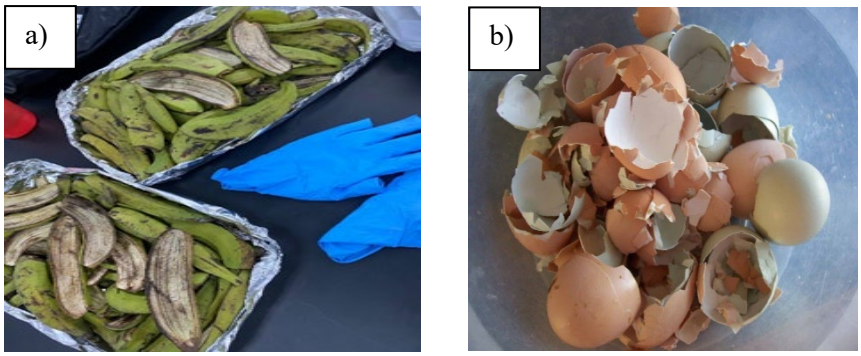

Fig. 1: a) The waste materials used, which are waste banana peel (WBP), and b) eggshell (ES) from small and medium industries (SMIs)

A plastic graduated cylinder was used to measure 1500 ml of water, which was then poured into the blender. The mixture was stirred for approximately 3 minutes, along with the specified amount of each sample. Then, the hand sheet of the former machine needs to be filled with water for up to 3 litres, and the materials in the blender were poured into the machine and stirred for 1 minute, followed by pressing the fast draining. The paper is rolled with a press felt until it sticks to the paper. This paper needs to be stressed to get a flat layer by using a pneumatic sheet press machine for 3 minutes and then drying it under the sunlight or iron until it is dried properly.

3. Results and Discussion

3.1 Microscope

Banana fibres may have a heterogeneous structure with varied lengths and diameters. The presence of cellulosic components from banana peels may increase the fibre's overall strength [3]. The microscopic analysis may reveal leftover cell structures from the banana peels, which can impact the paper's texture. The fibres from waste box material may have a more organised and aligned structure than banana fibres. Also, fine particles from smashed eggshells may be spread unevenly across the paper. Fig. 2 shows each sample of paper-making under a laboratory microscope.

The analysis reveals that sample WB (waste box) exhibits a neutral colour, consisting solely of waste box material used in papermaking. This sample is likely unsuitable for use due to its thin texture. This outcome can be attributed to the recycled fibres derived from discarded box materials, which play a significant role in conserving natural resources and minimising environmental impact. The recycling process allows fibres to be reused multiple times, contributing to sustainable paper production. The colour and texture of each sample differ because the materials used in paper production vary.

The samples of WB + ES (1.5 g) and WB + ES (3.5 g) both demonstrate how calcium carbonate disperses across the paper. The inclusion of waste box material in these samples enhances the texture, allowing for improved pressure handling during the pneumatic sheet press process. Similarly, samples WB + WBP (1.5 g) and WB + WBP (3.5 g) combine WB and WBP in varying amounts. These differences in composition result in papers with distinct textures and colours while maintaining a clean production process that highlights the fibre and cellulose content. Notably, WB + WBP (1.5 g) exhibits visible black areas containing WBP powder, indicating a high cellulose concentration. Finally, samples WB + WBP (2.5 g) + ES (1.5 g) and WB + WBP (4 g) + ES (2 g) combine WB, WBP, and ES in different proportions. Sample WB + WBP (4 g) + ES (2 g) produces a thicker paper compared to WB + WBP (2.5 g) + ES (1.5 g), thanks to the higher WBP content, which enhances durability. Microscopic analysis reveals prominent black spots corresponding to cellulose, while calcium carbonate from ES appears less pronounced [7].

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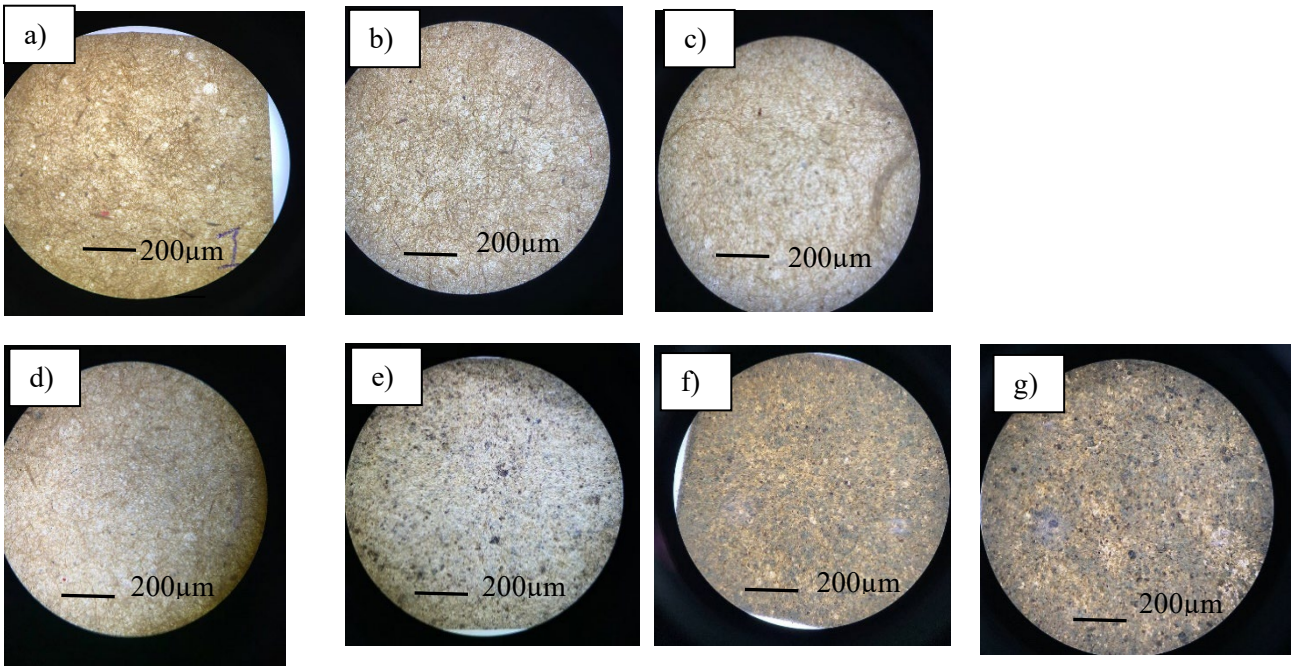

Fig. 2: The sample of paper making for different weight of materials of waste box (WB) and waste banana peel (WBP) used under laboratory microscope by using 100X magnification for a) WB (5g), b) WB + ES (1.5g), c) WB + ES (3.5g), d) WB + WBP (1.5g), e) WB + WBP (3.5g), f) WB + WBP (2.5g) + ES (1.5g), and g) WB + WBP (4g) + ES (2g)

3.1.1 Tensile Strength

In tensile strength testing, it shows an analysis of the bonding between different fibres. Strong bonding enhances tensile strength, while poor bonding may lead to weaker points in the paper [8]. The tensile strength of a material, including paper, refers to its ability to withstand a stretching force without tearing or breaking.

Fig. 3 presents the tensile strength results for seven paper composition samples, each measuring 1.27 cm in width and 7.6 cm in length. The tensile test was conducted at a speed of 20 mm/min. According to the graph, the tensile strength values for the paper compositions are as follows: 5WB is 0.658 N/mm², 5WB1.5E is 0.1347 N/mm², 5WB3.5E is 0.135 N/mm², 5WB1.5WBP is 0.403 N/mm², 5WB3.5WBP is 0.376 N/mm², 5WB2.5WBP1.5E is 0.534 N/mm², and 5WB4WBP2E is 0.313 N/mm². As observed in Fig. 3, the sample 5WB1.5E exhibits the lowest tensile strength, indicating that it is the weakest paper.

This finding demonstrates that paper containing a low amount (1.5 grams) of eggshells is unsuitable for production due to the insufficient calcium carbonate content in eggshells, which is critical as a filler in paper manufacturing. Even though fibres could potentially be extracted for use as fillers, they may lack the strength and properties necessary to produce durable and high-quality paper. Papers made from weak or brittle fibres are unlikely to meet the requirements for structural integrity and practical application [9].

In contrast, the sample of 5WB, which consists solely of waste box (WB) materials without any additional components, emerges as the strongest paper, as indicated by the graph. Waste boxes are rich in cellulose fibres, a key element that provides strength and structure to paper products. The WB material was carefully sorted, soaked for 24 hours, and processed immediately to maintain the quality of the fibres, preventing contamination. This meticulous handling of WB material justifies the high tensile strength of the 5WB sample, as seen in the graph.

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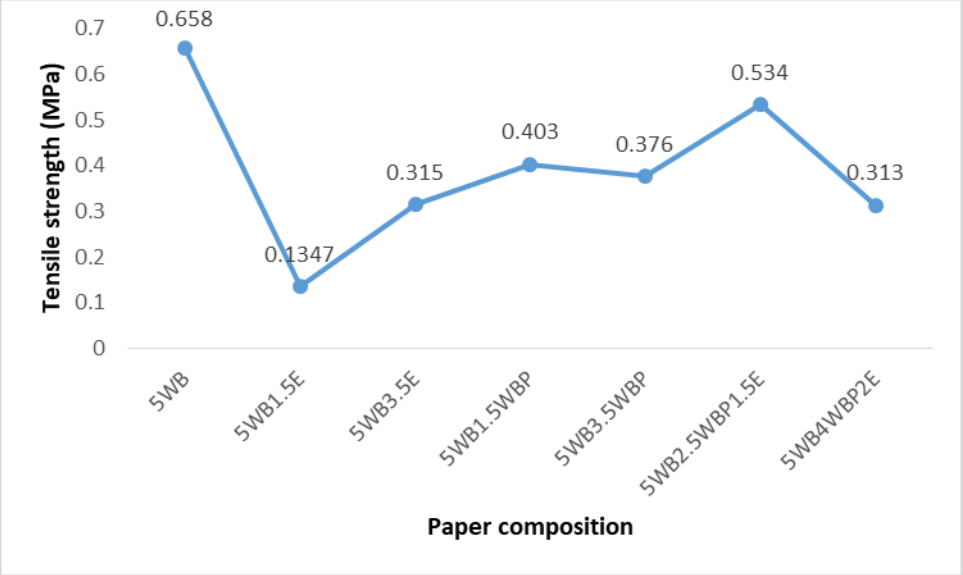

Fig. 3: Tensile strength of paper composite with eggshell filler with different ratios

4. Conclusion

The purpose of this research was to investigate the properties of paper made with a combination of raw materials such as waste banana peel, eggshell, and carton box. This study focused on testing such as tensile strength and tear tests to show the ability to make paper. The results show significant differences in all testing performed from data analysis of tensile strength and tear test. Testing for each paper making revealed a different colour and texture because of the presence of cellulose, hemicellulose and calcium carbonate in eggshells. The high strength of composite paper was shown for sample 5WB2.5WBP1.5E, which is 0.534 N/mm². It shows that the fillers are calcium carbonate, which is widely used as a filler in paper manufacturing due to its ability to fill the gaps between cellulose fibres. This results in a denser and more uniform paper structure. It enhances the surface smoothness, improves printability, and adds bulk to the paper without significantly increasing its weight. In conclusion, the incorporation of calcium carbonate from eggshells into the paper-making process enhances the paper's mechanical properties, durability, and overall quality. Its presence creates a robust structure that meets the demands of various practical uses while maintaining a balance of strength and flexibility.

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