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PHYSICAL CHARACTERIZATION OF PAPER MADE FROM DURIAN PEELS AND CORN STALKS

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Abstract

The increasing demand for paper has significantly impacted the environment due to the heavy reliance on wood as a primary raw material. This study investigates the feasibility of using durian (Durio zibethinus) peels and corn (Zea mays) stalks as alternative raw materials for paper production, focusing on their physical characteristics. The paper pulp was prepared using the soda pulping method with NaOH. Various ratios of durian peels and corn stalks were mixed: 1:0 (A), 0:1 (B), 1:1 (C), 2:1 (D), and 1:2 (E). Results indicated that type D produced the thickest paper, while type A produced the thinnest. The highest grammage was observed in type E, and the lowest in type D. Type C showed the highest absorbency. The tensile and tear indexes were highest in type D and lowest in type C. Type A had the highest mass density, whereas type D had the lowest. The findings suggest that a combination of durian peel and corn stalks exhibits diverse physical properties, indicating their potential use as an alternative to conventional wood-based paper. This approach could reduce the dependency on wood and contribute to environmental conservation.

INTRODUCTION

Paper is crucial in supporting various daily activities and functions [1]. In Indonesia, the paper industry primarily relies on wood sourced from forests as its raw material. However, the increasing development of the paper industry and other wood-dependent manufacturing sectors has depleted wood resources, making them more efficient and affordable [2]. Currently, a significant portion of the paper consumed is not recycled and ends up as waste, constituting 12.02% of Indonesia's total waste [4]. This accumulation of paper waste negatively impacts the environment, both in terms of hygiene and health [5].

To reduce the use of wood, it is necessary to develop alternative materials in papermaking. One approach to optimizing the utilization of timber as a raw material for pulp and paper is to identify alternative materials with potential for use in paper production [6]. According to Sundari et al. (2020), paper is generally made from cellulose fibers derived from wood raw materials. Cellulose fibers that are widely used as raw materials for making paper are natural wood fibers. Alternative natural fibers that contain cellulose fibers are non-wood natural fibers.

o mitigate the environmental impact and reduce reliance on wood, exploring alternative raw materials for papermaking is essential. One promising approach is identifying non-wood natural fibers that can be used in paper production. According to Hatta (2007) and Widiastuti et al. (2016), Durian peel, a byproduct with high cellulose content (approximately 50-60%), is one such material that needs to be utilized. Studies by Hatta (2007) and Widiastuti et al. (2016) highlight the potential of durian peel in papermaking, noting its lignin and starch content of around 5%. Similarly, corn stalks, often used as animal feed, contain cellulose (44.08%) and lignin (15%), making them a viable alternative for paper production. With a simple processing method, paper from durian skin can be used as raw material for making creative products such as office equipment, household decorations, cardboard, or unique papers [9]. According to Kurniawan W et al. (2015) dan Nasution (2010), urian peel waste contains fiber cells with long dimensions and thick enough fiber walls that will be able to bond well when given synthetic adhesives or mineral adhesives. Additionally, corn is a plant characterized by its hollow, grass-like stem, and nearly all parts of the corn plant can be utilized for various applications [12]. The community has used Corn stalk waste as animal feed, but its utilization has yet to be fully maximized [13]. This agricultural waste can be used as paper. The chemical composition of corn husk includes 15% lignin, 5.09% ash, 4.57% cyclohexane alcohol, and 44.08% cellulose [13].

Many studies have been conducted using alternative papermaking materials such as durian skin [7], [9], [14], [15], cocoa fruit skin [16], corn husk [17]–[19], peanut shells and chicken feathers [20], banana peel [21]–[23], matoa fruit peel [24], cassava peel [25], [26], bagasse waste and rice husk [2]. The findings from these studies indicate that the properties of paper are significantly influenced by the type of raw material and the processing method. Specifically, raw materials derived from durian skin, corn husk, and cassava skin exhibit superior paper properties, including higher tensile strength and tear resistance [6].

Based on the background explanation, this study aims to produce paper using alternative materials such as durian peel and corn stalks. The primary objective of this research is to explore the characteristics of paper made from the combination of durian peel and corn stalks by examining the individual properties of each material and conducting comparative analyses. This study aims to produce paper using durian peel and corn stalks as alternative materials. By examining the physical characteristics of paper made from these materials, we seek to provide a sustainable solution to reduce wood consumption in the paper industry. Additionally, we aim to compare the properties of paper made from durian peel and corn stalks with conventional HVS paper to evaluate their potential as viable alternatives.

RESEARCH METHODS

1. Materials

The materials used for paper production included durian peel (Durio zibethinus) and corn stalks (Zea Mays), along with additives such as 3% $KMnO_4$ and 10% NaOH. The recycled newspaper was also used as a supplementary component. Equipment involved in the characterization included a dynamometer for assessing tensile and tear strength, a screw micrometer for measuring paper thickness, and a digital balance for determining paper mass.

2. Preparation of paper

Durian peels and corn stalks were boiled separately for one hour to soften them. After cooking, they were blended until a soft texture was achieved. Concurrently, the newspaper was combined into a porridge-like consistency using a blender and boiled with 10% NaOH for 30 minutes to facilitate fiber breakdown. Each type of pulp—newspaper, durian peel, and corn stalk—was then combined in predetermined ratios and mixed thoroughly in a container containing 4 liters of water until a homogeneous pulp mixture was achieved. The mixture was poured into paper molds, ensuring even distribution, and left to dry naturally in sunlight. Once thoroughly dried, the resulting paper sheets were carefully labeled according to the specific treatment conditions. Table 1 displays the labeling of the resulting paper to facilitate analysis and comparison.

Table 1. Labeling the paper

Code	Material Ratio (Corn Stalks : Durian Peels)
A	0:1
B	1:0

C	1:1
D	1:2
E	2:1
F	(commercial paper)

3. Characterization of paper

The characteristics of the paper sheets were assessed through a series of measurements:

1. Thickness Measurement: Paper thickness was measured using a screw micrometer. Each paper sample was carefully placed between the anvils of the micrometer, ensuring uniform pressure, and the reading was recorded. Measurements were taken at multiple points on each sample to account for any variations in thickness.
2. Measurement of paper grammage (*G*) is crucial in various industries for determining paper strength, printability, and overall performance characteristics. According to the Indonesian National Standard, paper grammage refers to the mass of paper per unit area, typically expressed in grams per square meter (g/m^2) or GSM under standardized measurement conditions (BSN, 2010). This parameter is mathematically defined by Eq. (1), where *m* represents the mass of the paper in grams and *A* denotes the area of the paper in square meters.

$$G = \frac{m}{A} \quad (1)$$

3. Absorbency: The paper's ability to absorb liquids was evaluated by placing a specific quantity of oil on the surface and recording the time it took for the liquid to permeate and spread within the paper substrate in m^2. The measurement was conducted under controlled conditions, typically at room temperature (around 23°C) [28].
4. Tensile and Tear Strength: The tensile index was obtained by dividing the tensile resistance by the paper grammage. In contrast, the tear index was determined by the number of pulls per gram of paper that the paper could withstand without tearing. These metrics are crucial for assessing the mechanical properties and durability of the paper. The tensile index is obtained in the paper by dividing the tensile resistance by the paper grammage. In contrast, the tear index is determined by how many pulls per gram of paper the paper can withstand without tearing (Dharosno & Pundu, 2020). he tensile index and tear index can be calculated mathematically using Eq. (2) and Eq. (3), respectively, where E is tensile resistance (N/m^2), G is paper grammage (g/m^2), F is tear resistance (N).

$$Tensile\ Index = \frac{E}{G} \quad (2)$$

$$Tear\ Index = \frac{F}{G} \quad (3)$$

The last physical parameter that is important to measure on paper is density. This parameter provides essential information about the compactness of the paper. The density of paper is the ratio of the mass of paper to its volume, which is mathematically written in Eq. (4), where ϱ is the density of paper (g/cm^3), m is the mass of paper (g), and V is the volume of paper (cm^3).

$$\rho = \frac{m}{V} \quad (4)$$

By characterizing the physical properties of the paper made from durian peel and corn stalks, this study aims to provide a sustainable solution for reducing wood consumption in the paper industry and to evaluate the potential of these materials as viable alternatives to conventional HVS paper.

RESULTS AND DISCUSSION

Five types of paper were produced from processing durian peels and corn stalks. The five papers obtained from the processing are then compared with commercial paper, as shown in Figure 1. The paper is labeled according to the code specified in Table 1. Physical characteristics testing was then carried out on the six paper samples.

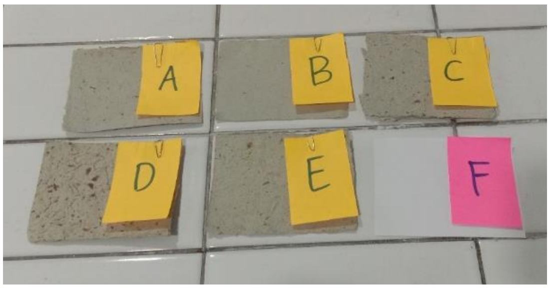

Figure 1. The appearance and coding of produced and comercial papers

1. Paper thickness

Measurements of paper thickness were conducted thrice on different surfaces of each paper sample, and the results were averaged to ensure accuracy. As shown in Table 2, the data indicate that the surfaces of the five paper samples are uneven. This conclusion is supported by the observed discrepancies between individual measurements, which highlight variations in the surface profiles of each sample. Among the samples, paper D exhibits the highest average thickness at 0.687 mm, while paper A has the lowest average thickness at 0.282 mm. These variations in thickness may be attributed to inconsistencies in the pulp processing during paper production, as suggested by [12]. Compared to commercial paper F, all five samples demonstrate a higher overall thickness, further emphasizing the unevenness in the production process.

Table 2. The results of paper thickness measurement

Paper Code	Measurement			Average (mm)
	1st (mm)	2nd (mm)	3rd (mm)	
A	0.236 ± 0.001	0.279 ± 0.001	0.332 ± 0.001	0.282 ± 0.050
B	0.339 ± 0.001	0.277 ± 0.001	0.320 ± 0.001	0.312 ± 0.035
C	0.249 ± 0.001	0.307 ± 0.001	0.313 ± 0.001	0.289 ± 0.041
D	0.736 ± 0.001	0.664 ± 0.001	0.662 ± 0.001	0.687 ± 0.049
E	0.381 ± 0.001	0.468 ± 0.001	0.422 ± 0.001	0.423 ± 0.044
F	0.103 ± 0.001	0.101 ± 0.001	0.104 ± 0.001	0.102 ± 0.002

2. Paper grammage
   3. The results of the paper grammage characterization for the samples are depicted in Figure 2. The measurements indicate that sample E exhibits the highest grammage while sample D has the lowest. Compared to commercial paper sample F, the grammage of the five produced papers varies significantly, reflecting their weight per unit area differences. The higher grammage of paper sample E can be attributed to its excellent fiber and water content. In contrast, the lower grammage of paper sample D is due to its reduced fiber and water content [9].

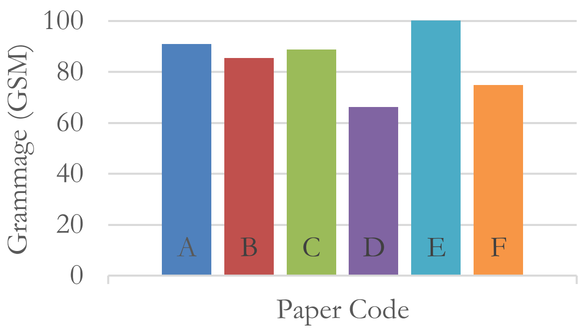

Figure 2. Grammage of papers

4. Paper absorbency

A liquid absorbency test was conducted to measure paper absorbency using 1 ml of oil droplets applied to both the produced and commercial papers. The droplets were allowed to settle for one minute before measurements were taken. The results, illustrated in Figure 3, reveal that four tested papers—labeled A, B, D, and E—exhibit absorbency characteristics similar to those of the commercial paper F. In contrast, paper C demonstrates a significantly higher absorbency than the other sample papers. The high absorbency of paper C can likely be attributed to its elevated porosity and increased surface area [30]. The specific combination of durian peel and corn stalk fibers in its composition appears to create more voids and capillaries within the paper structure, enhancing its capacity to absorb liquids. This structural configuration facilitates the capillary action and retention of liquid, leading to the observed high absorbency. The ability of paper to absorb liquids is a critical property, particularly for applications such as printing on tissue paper, where high absorbency is desirable [31].

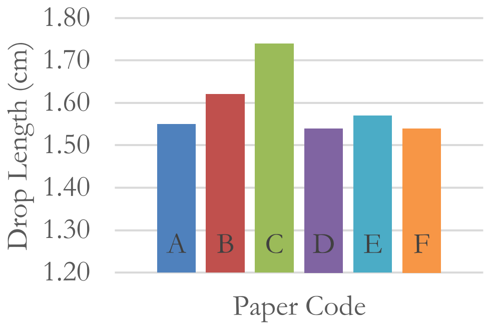

Figure 3. Oil absorbency of papers

5. Tensile index

The tensile index was determined using a dynamometer, with the area of each paper sample equalized to ensure comparability. The results, depicted in Figure 4, show that paper D exhibits the highest tensile index, while paper C has the lowest. Paper D has a slightly higher tensile index than commercial paper F, indicating its superior resistance to tensile forces. The lower tensile index observed in paper C, which incorporates corn husk, can be attributed to the higher lignin content in corn stalks, resulting in reduced tensile strength [12]. In addition, the low tensile strength of paper C can be attributed to the poor bonding between fibers in this specific combination ratio, resulting in weaker paper. Ineffective fiber bonding reduces the paper's overall structural integrity and tensile strength [32].

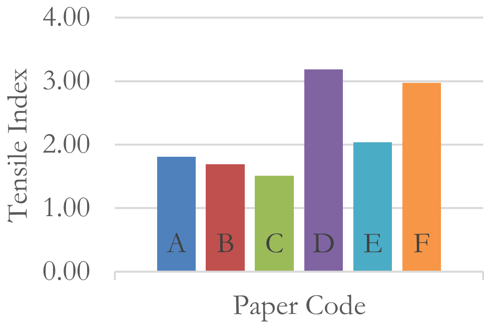

Figure 4. Tensile index of papers

6. Tear index

As illustrated in Figure 5, the tear index calculations show that paper D exhibits the highest tear index while paper C has the lowest. Compared to commercial paper F, paper D has a slightly higher tear index, indicating that it is more resistant to tearing than the other sample papers. The tear resistance of paper is influenced by several factors, including the length of the paper fibers, sheet flexibility, and grammar [33]. The high tear index of paper D can be attributed to the adequate bonding between materials in this combination ratio. Strong bonds ensure the paper can withstand the stress and strain applied during tearing without easily rupturing [5].

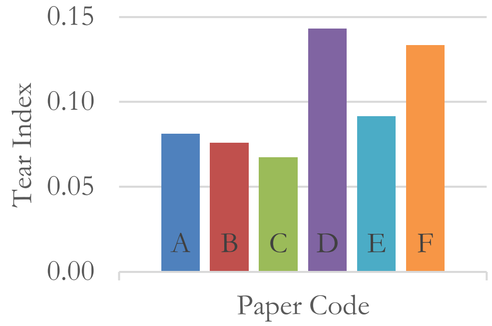

Figure 5. Tear index of papers

7. Density

The measurement of paper mass density involves determining the mass of paper using digital scales and calculating the volume based on specified sample areas and average thickness. The paper mass density calculation results are depicted in Figure 6, where paper A exhibits the highest density and paper D the lowest. This indicates that paper A is denser than the other sample papers. All five papers display significantly lower mass densities than commercial paper F. The lower mass density of paper is influenced by higher fiber content, represented by paper grammage, which affects the resulting sheet's flexibility [31].

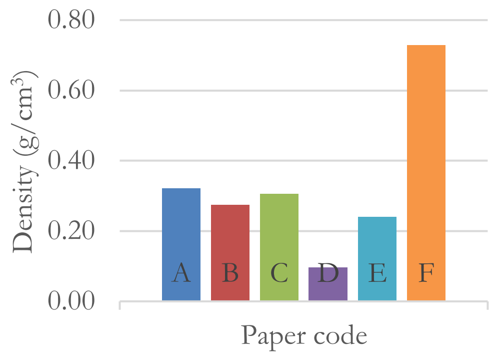

Figure 6. Density of papers

Using durian peels and corn stalks as raw materials for paper shows significant potential in producing paper with various physical properties. Variations in the proportions of these raw materials result in paper with diverse thicknesses, grammage, absorbency capacity, tensile index, tear index, and density. These findings suggest that this combination of raw materials can be tailored to meet the specific requirements of different paper applications, thereby reducing dependence on wood as the primary raw material in the paper industry.

CONCLUSION

The study demonstrates that paper from durian peels and corn stalks exhibits varied physical characteristics compared to commercial paper. Significant findings include uneven thickness among the samples, with paper D being the thickest and paper A the thinnest, indicating potential inconsistencies in pulp processing. Grammage measurements show considerable variability, with paper E having the highest and paper D having the lowest grammage. Moreover, absorbency tests reveal that paper C stands out for its high absorbency, likely due to its unique fiber composition fostering increased porosity and capillary action. Tensile and tear strength assessments highlight paper D as the most robust sample, suggesting adequate fiber bonding in its composition. However, all samples exhibit lower mass densities than commercial paper F, which may affect their suitability for specific applications requiring greater density and stiffness.

Future studies should prioritize improving the consistency of paper thickness and enhancing fiber bonding during pulp processing. Addressing variations in paper from durian peels and corn stalks could lead to more uniform products. Optimizing fiber and water content to adjust paper weight without sacrificing strength is crucial for developing papers suitable for diverse applications. Exploring methods to increase paper density while maintaining flexibility would expand the potential uses of these sustainable materials in the paper industry.

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