

Physical Characteristics of Corn Husk–Areca Nut Husk Paper Biocomposites Containing Gambir Extract

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ABSTRAK

Pemanfaatan limbah lignoselulosa sebagai bahan baku alternatif kertas merupakan salah satu strategi untuk mendukung pengembangan material berkelanjutan dan ekonomi sirkular. Penelitian ini bertujuan untuk menghasilkan dan mengevaluasi karakteristik fisik bio-komposit kertas berbasis kulit jagung (*Zea mays* L.) dan kulit buah pinang (*Areca catechu* L.) dengan penambahan ekstrak gambir (*Uncaria gambir* Roxb.). Penelitian menggunakan Rancangan Acak Lengkap satu faktor dengan dua formulasi rasio serat, yaitu 70:30 dan 50:50, masing-masing dengan tiga ulangan. Biomassa diproses melalui delignifikasi metode soda, pembuburan, pencampuran dengan pengikat pati tapioka dan ekstrak gambir, serta pembentukan lembaran secara manual. Parameter utama yang dievaluasi adalah ketebalan, sedangkan karakteristik visual, penyerapan air, integritas struktur, dan kondisi selama penyimpanan diamati secara kualitatif. Formulasi 70:30 menghasilkan ketebalan rata-rata $1,20 \pm 0,10$ mm, lebih tinggi dibandingkan formulasi 50:50 sebesar $0,18 \pm 0,02$ mm. Hasil menunjukkan bahwa rasio serat memengaruhi karakteristik fisik lembaran yang dihasilkan. Bio-komposit ini menunjukkan potensi pemanfaatan kulit jagung dan kulit pinang sebagai bahan baku alternatif untuk pengembangan material kertas berbasis biomassa, meskipun pengujian kuantitatif lebih lanjut masih diperlukan untuk menentukan sifat mekanik dan fungsionalnya.

Kata kunci: bio-komposit kertas; gambir; kulit jagung; kulit pinang; lignoselulosa

ABSTRACT

The utilization of lignocellulosic waste as an alternative raw material for paper represents a potential strategy for developing sustainable materials and supporting the circular economy. This study aimed to produce and evaluate the physical characteristics of paper biocomposites based on corn husk (*Zea mays* L.) and areca nut husk (*Areca catechu* L.) containing gambir (*Uncaria gambir* Roxb.) extract. A completely randomized design with one factor and two fiber-ratio formulations, 70:30 and 50:50, was applied with three replicates per treatment. The biomass was processed through soda delignification, pulping, mixing with tapioca starch as a binder and gambir extract, and manual sheet formation. Thickness was evaluated as the primary parameter, while visual characteristics, water absorption, structural integrity, and storage conditions were qualitatively observed. The 70:30 formulation produced a mean thickness of 1.20 ± 0.10 mm, which was higher than that of the 50:50 formulation at 0.18 ± 0.02 mm. The findings indicate that the fiber ratio influenced the physical characteristics of the resulting sheets. These results demonstrate the potential utilization of corn husk and areca nut husk as alternative raw materials for biomass-based paper materials, although further quantitative evaluation is required to determine their mechanical and functional properties.

Keywords: areca nut husk; corn husk; gambir; lignocellulose; paper biocomposite

I. INTRODUCTION

1. Background

The growing demand for renewable fiber-based materials, coupled with the need to reduce the use of fossil-based raw materials and increase the utilization of biomass waste, is driving the development of lignocellulosic materials from non-wood sources. Agricultural residues are an abundant source of lignocellulosic biomass with the potential to be converted into various value-added products, including pulp, paper, biocomposites, and fiber-based materials. This approach aligns with the principles of the circular economy, which views residues as resources whose value can be sustained through processes that repurpose them into new products (Mujtaba et al., 2023). Thus, the development of materials derived from agricultural residues not only has the potential to reduce waste burdens but also opens opportunities for utilizing local biomass as a feedstock for more sustainable materials. This context is relevant to the potential of agricultural biomass in North Sumatra. The North Sumatra Provincial Central Statistics Agency reported that the production of dried shelled corn with a moisture content of 14% in 2024 reached 1.37 million metric tons, an increase of 2.28% compared to the 2023 production of 1.34 million metric tons (North Sumatra Provincial Central Statistics Agency, 2025). The high level of corn production indicates the availability of crop residue biomass that has the potential for further utilization. One part of the plant that shows promise as a source of fiber is the corn husk (*Zea mays* L.). Previous research has shown that corn husks contain cellulose, which supports their use as a raw material for fiber-based products. Suseno et al. (2021) reported the use of corn husks in the production of tissue paper, while other studies have shown that corn husk fibers can also be developed into paper and biocomposite materials through various treatment and modification processes. More broadly, non-wood agricultural residues have been viewed as an alternative fiber source for pulp and paper because they can reduce dependence on wood raw materials (Worku et al., 2023). Ibrahim et al. (2019) further characterized the chemical composition of corn husk and reported that, among corn plant parts, corn husk exhibited the highest cellulose content and the most favorable surface morphology for biomaterial development. However, using corn husks as the sole raw material does not always result in sheets with optimal characteristics. The final characteristics of fiber-based materials are greatly influenced by the type of raw material, fiber structure, chemical treatment, sheet-forming process, and interfiber interactions. Research by Bhardwaj et al. (2023) shows that corn husks can be used as a paper base material through the soda pulping process and subsequently modified to achieve specific functional characteristics. Ratna et al. (2023) also demonstrate that cellulose derived from corn husks can be used in the development of biocomposite materials. These findings indicate that corn husks hold promise as a source of fibrous material, but the characteristics of the resulting material still depend on the formulation and processing techniques. Therefore, combining corn husks with other lignocellulosic fiber sources is a relevant approach worth exploring. Areca-derived fibers have likewise been evaluated as reinforcement in polymer-based composites, including leaf sheath fiber-reinforced composites (Praveena et al., 2022) and hybrid composites developed for thermal-insulation applications (Mahmud et al., 2025). One type of biomass that has the potential to be combined with corn husks is areca nut husks (*Areca catechu* L.). Areca nut husks are lignocellulosic residues composed of structural components such as cellulose, hemicellulose, and lignin. Yuan et al. (2023) demonstrated that areca nut husks possess chemical and fiber structural characteristics that support their use as a fibrous biomass feedstock, although their lignin characteristics must be considered during processing. A study by Süfer et al. (2024) also indicated that areca nut husk fibers have potential for

development in various lignocellulosic-based material applications. Furthermore, Madyaratri et al. (2025) identified Areca catechu-based biomass as a potential source for the development of biocomposites and cellulose-based materials. This potential provides a basis for investigating areca nut husks as a fiber component in biocomposite sheets made from agricultural residues. In the formation of fiber-based sheets, the proportion of raw materials can affect fiber distribution, interfiber network formation, density, and the physical characteristics of the resulting sheet. Changes in the composition of the two fiber sources can also result in differences in the structure and uniformity of the sheet, as each type of biomass has distinct fiber characteristics and lignocellulosic components. Therefore, variations in the proportions of corn husks and areca nut husks need to be experimentally tested to determine how changes in the ratio of these two materials relate to the physical characteristics of the resulting biocomposite. In this study, two fiber mass ratios were used—70:30 and 50:50 between corn husks and areca nut husks—so that the effects of changes in fiber composition could be observed under the same processing conditions. In addition to fiber composition, the use of binders can play a role in the formation of sheet structures. Starch is a renewable material that has been used in paper and biocomposite technologies because it can interact with fibers and help improve the structural integrity of the material (Hubbe, 2024; Nasir et al., 2026). In this study, tapioca starch was used as a starch-based binder, with a fixed amount incorporated into all formulations. Thus, the presence of tapioca was not a treatment variable but rather a supporting component used uniformly to aid in sheet formation. This approach was essential to ensure that the observed differences in characteristics could be primarily attributed to changes in the ratio of corn husk to areca nut husk fibers. Starch-based adhesives prepared from a similar starch source have also been shown to improve surface strength and printing quality when applied in paper coating formulations (Wang et al., 2013)..

2. Problem Formulation

The problem formulation in this study concerns how the research titled "Physical Characteristics of Corn Husk–Areca Nut Husk Paper Biocomposites Containing Gambir Extract" can be conducted in accordance with established procedures and in a timely manner.

3. Research Objectives

The objective of this study is to determine the findings of the research titled "Physical Characteristics of Corn Husk–Areca Nut Husk Paper Biocomposites Containing Gambir Extract."

4. Research Benefits

The benefit of conducting this research is to provide information to the medical and academic communities regarding the findings on "Physical Characteristics of Corn Husk–Areca Nut Husk Paper Biocomposites Containing Gambir Extract," which may offer implications for future research.

II. RESEARCH METHOD

Research Location and Time

This study was conducted as a laboratory-based experimental study from May to August 2026. Corn husks (*Zea mays* L.) were obtained from Tigabinanga District, Karo Regency, while areca nut husks (*Areca catechu* L.) were obtained from STM Hilir District, Deli Serdang Regency, North Sumatra, Indonesia. All research procedures, including raw material preparation, delignification, pulp preparation, bio-composite formulation, sheet formation, drying, finishing, and product characterization, were conducted at the Chemistry Laboratory and Physics Laboratory, Faculty of Mathematics and Natural

Sciences, Universitas Negeri Medan. The location and research period correspond to the implementation of the experimental procedures.

Experimental Design

The study employed a one-factor Completely Randomized Design (CRD). The treatment factor was the mass ratio of corn husk fiber to areca nut husk fiber, consisting of two treatment levels: 70:30 (formulation A) and 50:50 (formulation B). Each treatment was prepared in three independent experimental units, resulting in six experimental units in total. Formulation A consisted of 70 g of corn husk and 30 g of areca nut husk, whereas formulation B consisted of 50 g of corn husk and 50 g of areca nut husk. The total dry fiber mass used in each experimental unit was 100 g. Gambir extract (*Uncaria gambir* Roxb.) and tapioca starch binder were maintained at the same amount in all experimental units and were not considered treatment factors. Thus, the independent variable was the fiber ratio of corn husk to areca nut husk, while the physical characteristics of the resulting sheets were the response parameters. The treatment formulations are presented in Table 1.

Table 1. Bio-composite formulations based on the corn husk-to-areca nut husk fiber ratio

Formulation	Corn husk : areca nut husk ratio	Corn husk (g)	Areca nut husk (g)	Gambir extract	Tapioca binder
A	70:30	70	30	Constant	Constant
B	50:50	50	50	Constant	Constant

Each formulation was prepared in triplicate, designated A1, A2, and A3 for formulation A (70:30) and B1, B2, and B3 for formulation B (50:50). All experimental units underwent the same processing procedures so that differences in the observed characteristics could primarily be associated with changes in the fiber ratio.

Materials and Equipment



(a) Corn husk

(b) Areca nut husk

(c) Gambir

Figure 1. Raw materials used for the preparation of the paper biocomposites

The materials used included corn husk, areca nut husk, 5% sodium hydroxide (NaOH) solution for delignification, gambir (*Uncaria gambir* Roxb.), tapioca starch as a starch-based binder, and water for washing, cooking, pulping, gambir extraction, and binder preparation. The equipment included washing containers, knives or scissors, a balance, cooking vessels, a heating device, a thermometer, a blender, a stirring device, a sheet-forming mold equipped with a T-120 mesh screen, absorbent cloth, an electric iron for finishing, a digital thickness gauge, and a camera for documentation. The general papermaking procedure was adapted from a previously reported method for corn-husk-based paper production (Suseno et al., 2021), with modifications involving the combination of corn husk and areca nut husk fibers and the incorporation of tapioca starch and gambir extract.

Raw Material Preparation

Corn husk and areca nut husk were sorted to remove dirt and visibly deteriorated portions. The materials were then washed with water to remove adhering impurities and mechanically cut into pieces approximately 1–2 cm in size.

Soda Delignification

Delignification was performed using a soda pulping method with 5% NaOH solution at 80–90°C for 120 min. A biomass-to-delignification-solution ratio of 1:10 was used. The procedure was adapted from previously reported approaches for processing non-wood fibers, with adjustments for the biomass used in this study (Suseno et al., 2021). The cut biomass was immersed in the NaOH solution and heated at 80–90°C for 120 min.

Pulp Preparation

The delignified fibers were processed using a blender with the addition of water as needed until a fiber suspension or pulp was obtained. Corn husk and areca nut husk pulp were subsequently prepared according to the treatment ratios of 70:30 and 50:50 based on dry fiber mass.

Gambir Extraction and Incorporation

Gambir extract was prepared by dissolving 3 g of solid gambir in 100 mL of warm water. The mixture was then filtered to separate insoluble material and obtain the gambir extract filtrate.

Data Analysis

Thickness data from the three experimental units in each treatment were tabulated according to experimental-unit codes A1–A3 and B1–B3. For each treatment, the data were expressed as the mean $\pm$ standard deviation (SD). Sample standard deviation was calculated using the following equation:

$$SD = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$$

where SD is the sample standard deviation, x_i is the observation from each experimental unit, $\bar{x}$ is the treatment mean, and n is the number of experimental units. The difference in mean sheet thickness between the 70:30 and 50:50 formulations was analyzed using an independent-samples t -test at a significance level of $\alpha=0.05$ and a 95% confidence level.

III. RESULT

Results



Figure 2. GA-PAPER

Physical Characteristics of GA-Paper

The physical characteristics of GA-Paper produced from the two corn husk-to-areca nut husk fiber ratios were evaluated descriptively after sheet formation, drying, and hot-pressing. Both formulations produced brownish sheets with visible natural fiber characteristics. The brownish appearance was associated with residual pigments and non-cellulosic components that were not completely removed during the alkaline treatment. The surface texture varied among sheets, ranging from relatively rough to smoother surfaces after hot-pressing. Both formulations formed relatively compact sheets that could be manually bent repeatedly without visible cracking or breakage. No consistent visual difference in color, surface texture, or overall sheet integrity was identified between the 70:30 and 50:50 formulations. Therefore, the variation in fiber ratio did not produce an obvious qualitative difference in the general appearance of the resulting sheets under the conditions used in this study.

Sheet Thickness

The thickness measurements of GA-Paper are presented in Table 2. The 70:30 formulation produced thickness values of 1.10, 1.20, and 1.30 mm for experimental units A1, A2, and A3, respectively. The mean thickness was 1.20 ± 0.10 mm. In comparison, the 50:50 formulation produced thickness values of 0.16, 0.18, and 0.20 mm for experimental units B1, B2, and B3, respectively, with a mean thickness of 0.18 ± 0.02 mm.

Table 2. Thickness of GA-Paper at different corn husk-to-areca nut husk fiber ratios

Formulation	Experimental unit	Thickness (mm)
A (70:30)	A1	1.10
A (70:30)	A2	1.20
A (70:30)	A3	1.30
B (50:50)	B1	0.16
B (50:50)	B2	0.18
B (50:50)	B3	0.20

The mean thickness of the 70:30 formulation was approximately 6.67 times greater than that of the 50:50 formulation. An independent-samples *t*-test using the unequal-variance approach (Welch's *t*-test) showed a statistically significant difference between the two formulations ($t = 17.32$, $df = 2.16$, $p = 0.0023$). The estimated mean difference was 1.02 mm, with a 95% confidence interval of 0.78–1.26 mm.

Water Exposure and Physical Stability

Qualitative water-exposure observations showed that both formulations absorbed water when exposed to prolonged wet conditions. However, the sheets did not undergo visible structural disintegration during the observation period. The sheets retained their general form and remained physically coherent, although changes in surface condition were observed after water exposure. These observations indicate that GA-Paper was water-absorbent but retained its structural integrity during the tested observation period. Because water uptake, water contact angle, dimensional stability, and water resistance were not quantitatively measured, the present findings should not be interpreted as evidence of water resistance or waterproof performance.

Storage Stability and Visible Fungal Growth

During the initial storage observation under uncontrolled ambient room conditions, neither the 70:30 nor the 50:50 formulation showed visible fungal growth. The sheets remained generally intact, and no obvious surface colonization was observed during the observation period. A change in sheet color was observed during storage, whereas the overall texture and shape remained relatively stable. The absence of visible fungal growth in this observation provides an initial indication of physical and biological stability under the specific storage conditions used in this study. However, the observation was conducted without controlled relative humidity, temperature, standardized fungal inoculation, fungal species identification, or quantitative measurement of fungal coverage. Consequently, these results cannot be interpreted as evidence of antifungal activity or definitive fungal resistance of GA-Paper.

IV. KESIMPULAN

This study demonstrated the technical feasibility of producing a lignocellulosic paper biocomposite (GA-Paper) from corn husk (*Zea mays* L.) and areca nut husk (*Areca catechu* L.) using soda delignification, tapioca starch as a binder, and a fixed amount of gambir (*Uncaria gambir* Roxb.) extract as a functional component. The variation in the corn husk-to-areca nut husk fiber ratio significantly affected the thickness of the resulting sheets. The 70:30 formulation produced a significantly thicker sheet (1.20 ± 0.10 mm) than the 50:50 formulation (0.18 ± 0.02 mm) ($p < 0.05$). Both formulations produced brownish sheets

with visible lignocellulosic characteristics and maintained their general structural integrity during manual handling. The sheets absorbed water but did not show visible structural disintegration during the observation period. In addition, no visible fungal growth was observed during the initial ambient storage period. However, because water resistance and fungal growth were evaluated qualitatively under uncontrolled conditions, these observations should not be interpreted as definitive evidence of water resistance or antifungal activity. Overall, the results indicate that the corn husk-to-areca nut husk fiber ratio is an important factor influencing the physical structure of GA-Paper, particularly its thickness. The findings provide preliminary evidence for the utilization of these agricultural residues as alternative raw materials for lignocellulosic paper biocomposites. Further research should include larger replication and standardized sheet formation, as well as quantitative evaluation of mechanical properties, grammage, density, water absorption, dimensional stability, and microbiological resistance to determine the material's suitability for specific applications..

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