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Physical and mechanical properties of fiberboard made from corn cob and coconut fiber with natural adhesives

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Abstract
Developing fiberboard from agro-industrial and natural waste has a significant impact on environmental practices. Fiberboards made from corncobs and coconut fiber have become a desirable by-product that can serve as a wood substitute. This research aims to analyze the physical and mechanical properties of fiberboard composites created from coconut husks and corn cobs, using natural adhesives like tapioca glue and citric acid. Corn cob particles and coconut fruit fibers were weighed in a 1:1 ratio. Tapioca glue or citric acid was then added in varying percentages: 10%, 14%, 18%, 22%, and 26% of the total mixture. This blend was poured into molds, spread evenly with a spatula, and pressed under 30 kg/cm² (426.7 psi). Subsequently, the samples were carefully removed for physical and mechanical testing. The findings of the study indicated that the different mass variations of corncobs and coconut fibers mixed with natural adhesives successfully produced fiber composites that met the Japanese Industrial Standards (JIS) A 5095:2003 for the "hardboard" classification. The most effective composition was found in sample A5, which contained 26% tapioca glue. Tapioca glue proved to be the superior natural adhesive, surpassing citric acid. Tests conducted on fiberboard A5 revealed the highest density at 0.90 gr/cm³, the lowest porosity at 7.35%, optimal impact strength at 119.99 J/m², tensile strength of 730.50 MPa, and flexural strength of 109.34 MPa. Therefore, this fiberboard demonstrated favorable physical and mechanical properties.

Keywords:
Fiberboard composites, coconut fiber, corn cob, natural adhesive.

1 Introduction

The population growth is directly correlated with the increasing demand for wood, which is used in construction and furniture. This increase is in stark contrast to the diminishing supply of high-quality wood in forests, posing a significant challenge to Indonesia's wood processing sector. Currently, the availability of raw wood is severely limited and difficult to obtain. This issue arises from an imbalance between the rate of wood consumption and the rate of tree planting to replace harvested wood. Simultaneously, as the population grows, the demand for wood for furniture manufacturing, construction, and other purposes continues to escalate. Therefore, both the industry and the community require processed products that utilize alternative raw materials to replace conventional wood [1].

Fiberboard, also known as particle board, is a commonly used alternative to wood. Fiberboard is a composite product that serves as an alternative material. It is made from lignocellulosic materials, wood fibers, or similar components. Fiberboard consists of and is bonded by primary connections derived from other materials (adhesives) or can also originate from the raw material itself (lignin). Fiberboard possesses good mechanical strength and facilitates ease of processing, making it a reliable construction material [2].

Wood fiber serves as the primary constituent of fiberboard, particularly hard density fiberboard [3]. However, evolving environmental concerns and recycling initiatives have expanded the material palette to include alternatives such as waste paper, corn silk, and bagasse [3]. These fibers are typically sourced from various wood species or derived from wood residues such as chips, shavings, and sawdust [3]. However, evolving environmental concerns and recycling initiatives have broadened the material palette, incorporating alternatives, such as waste paper, corn silk, and bagasse [4]. While wood fiber remains predominant due to its abundant availability and robust properties, other natural fibers like corn fiber and coconut fiber (coir) offer distinct advantages. Corn fiber, sourced from corn husks or stalks, boasts moderate strength and biodegradability, finding niche applications in textiles and bio-based materials [5].

On the other hand, coconut fiber, obtained from coconut husks, presents a range of properties depending on its type - brown or white coir [6]. Both types exhibit remarkable strength, durability, and sustainability, making them suitable for diverse applications ranging from doormats and brushes to agricultural substrates and construction materials. Thus, while wood fiber remains the cornerstone of fiberboard production, the inclusion of alternative fibers underscores a growing emphasis on sustainability and resource diversification within the industry. Wood fiber stands out with robust tensile strength and is ideal for load-bearing applications such as Medium-Density Fiberboard (MDF) production [7]. In contrast, corn fiber offers moderate strength suitable for non-load-bearing applications, such as textiles and bio-based materials [8]. Meanwhile, coconut fiber (coir) impresses exceptional tensile strength, particularly in brown coir, making it a preferred choice for sturdy applications such as doormats and ropes [9].

Several studies have been conducted on the production of fiberboard or fiberboard composites from agricultural waste or by-products using natural adhesives. Corn cobs and coconut fiber are among the materials studied for fiberboard production. Corn cobs contain 41% cellulose, while coconut husks have a cellulose content of 43% and lignin content of 33% [10], [11]. The research conducted by Yusriani et al. [11] involved the use of banana stem fibers and corn cobs as raw materials for engineered fiberboard, modified with epoxy resin adhesive. Coconut fruit fibers, commonly known as coir, have also been used as a base material for fiberboard using natural adhesives like tapioca glue [12]. In addition to tapioca glue, citric acid has been used as an adhesive in the production of fiberboard based on peanut shell waste [13].

In the production of fiberboard, achieving good mechanical properties requires combining two or more materials with an adhesive. Adhesives are necessary to enhance the strength of fiberboard and prevent it from easily disintegrating. In addition to fiber and composite materials, the type of adhesive used also impacts the mechanical characteristics of the fiberboard composite product [14]. Synthetic adhesives such as Urea Formaldehyde (UF) are commonly used in fiberboard manufacturing. These synthetic adhesives have advantages such as colorless UF, good adhesive quality, fast curing time, and cost-effectiveness. However, synthetic adhesives like UF can emit formaldehyde [15]. Therefore, some studies have explored natural materials such as citric acid and tapioca glue as adhesives in fiberboard production [12], [13].

Based on previous research, it has become increasingly clear that the utilization of natural fibers has garnered significant attention in contemporary research, primarily because of their abundant availability. Empirical evidence suggests a strong feasibility for producing fiberboard utilizing composites derived from coconut husks and corncobs, in conjunction with natural adhesives such as tapioca flour or citric acid. However, there remain challenges that need to be addressed, such as optimizing the manufacturing process, ensuring durability, and assessing the environmental impact throughout the product lifecycle. The present study was conducted to manufacture fiberboard from corncobs and coconut fibers by employing natural adhesives. This offers a sustainable alternative to conventional wood for use in construction and various other applications. Therefore, the objectives of this study are to analyze the physical and mechanical properties of fiberboard made from coconut husks and corn cobs with natural adhesives.

Testing the physical and mechanical properties of fiberboard are crucial to ensure its quality and performance. Analyzing strength, durability, and resistance to impact and fatigue can determine how well the material holds up in various applications. These tests also aid in comparing them to conventional wood-based fiberboards, thereby guiding improvements in manufacturing processes for sustainable alternatives.

2 Materials and Methods

2.1 Materials and Instruments

The research was conducted focusing on the creation of composite fiberboards using corn cob, coconut fiber, tapioca glue, and citric acid. The process was carried out at the Basic Chemistry Laboratory of North Sumatra University and the Mechanical Engineering Program Laboratory at Asahan University.

In this study, the materials used included coconut fiber particles, serving as a filler in the composite fiber wood; corn cob particles, also utilized as a filler [16]; NaOH analytical grade from Merck (Germany) for removing lignin from palm frond fibers [17]; tapioca glue and citric acid analytical grade from Pudak scientific (Indonesia) as adhesives; and wax mirror glaze for lubricating the samples to prevent sticking to the mold.

The equipment employed in the study comprised an 80-mesh sieve for filtering corn cob powder; a digital balance for measuring the weight of corn cobs, coconut fibers, and adhesives; a hot press used for the pressing process; two iron plates serving as a base and cover for the mold; and a mold used to shape samples, measuring 100×20×10 mm. Additional tools included a 500 mL beaker glass for mixing sample components, aluminum foil to line the mold during pressing, a blender for grinding the corncobs, a stopwatch for timing the fiber soaking process, and a Universal Testing Machine (UTM) and Gotech Impactor to measure the mechanical and physical properties of the fiberboards. Other supporting tools such as rulers, knives, and scissors were also used.

2.2 Preparation of Coconut Fiber

The preparation process for coconut fiber was prepared by separating the coconut husk from the outer part of the coconut [18]. The processed fibers (500 g) were then soaked for 24 h and cleaned with water. After cleaning, the coconut fiber was sun-dried for 24-36 hours until it dried completely. Finally, the dry coconut fiber was cut into small pieces, each measuring with a ruler between 2-7 cm.

2.3 Preparation of Corn Cob

The preparation of corncobs was started by separating the cobs from the kernels [19]. Separated corncobs (500 g) were cleaned with water. These corncobs were sun-dried for 24-36 hours until they were completely dry. The dry corncobs were then cut into smaller pieces. These pieces were further ground into small particles using a crushing machine and sifted through an 80-mesh sieve.

2.4 Preparation of Tapioca Glue

A mixture of tapioca flour and water was first weighed using a digital scale. The two ingredients were mixed in a 50:50 ratio [20]. This mixture was then heated on a stove at medium temperature until it became thick and transparent, forming cassava glue.

2.5 Preparation of Citric Acid

Citric acid and water were weighed on a digital scale and mixed at a 60:40 ratio [21]. This mixture was heated on a stove at medium temperature until it thickened, forming a citric acid solution.

2.6 Manufacturing of Composite Fiberboard using Tapioca Glue Matrix

In the manufacturing of composite fiberboard with a tapioca glue matrix, corncob particles and coconut fibers were weighed in a 1:1 ratio. The percentage of cassava glue in the total mix varied, including 10%, 14%, 18%, 22%, and 26%, measured using a digital analytical balance. The mold was cleaned from dirt to prevent it from sticking and lined with aluminum foil on the iron plates on the base and cover. Mirror glaze was applied to the mold and iron plates to prevent the mixture from sticking. A mixture of natural adhesive, corncob, and coconut fiber was prepared using a mixer. It was then poured into the mold and spread evenly with a spatula. The mold was then covered with an aluminum foil-lined iron plate and pressed at 30 kg/cm² (426.7 Psi) for 15 minutes at 55°C-65°C. After pressing, the sample was removed from the mold and underwent physical and mechanical property tests.

2.7 Manufacturing of Composite Fiberboard using Citric Acid Matrix

In the manufacturing of composite fiberboard with a citric acid matrix, corncob particles and coconut fibers were weighed in a 1:1 ratio with varying percentages of citric acid in the mix (10%, 14%, 18%, 22%, and 26%). The fiber particles and adhesive mixture were oven-dried at 80°C for 24 hours [22]. The mold was cleaned and lined with an aluminum foil. Mirror glaze was applied to prevent sticking. The natural adhesive was mixed with corn cob and coconut fiber using a spatula, poured into the mold, and spread evenly. The mold was covered with an aluminum foil-lined iron plate and pressed at 70 kg/cm² (1000 psi) for 15 min at 180°C. After pressing, the sample was removed and tested for its physical and mechanical properties.

2.8 Physical Properties Testing Procedure

The density of the composites was determined by dividing the mass of the cylindrical samples by their volume, as shown in Eq. 1. In addition, porosity measurement follows Eq. 2. Three replicates were tested, and the averages of these measurements were reported. A digital balance and vernier caliper were used to measure the mass and dimensions in accordance with ASTM C134 [23].

$$\rho = \frac{m}{V} \tag{1}$$

where ρ is the density of the composite material (g/cm³), m is the mass of the sample (g), and V is the volume of the sample (cm³).

$$P = \frac{V_{void}}{V_{total}} \times 100\% \tag{2}$$

where P is the porosity of the composite material (%), V_{void} is the volume of voids or pores within the sample (cm³), and V_{total} is the total volume of the sample (cm³).

2.9 Mechanical Properties Testing Procedure

All samples were cut and prepared in accordance with ASTM D256, resulting in six replicas with dimensions of 100×20×10 mm. Subsequently, the specimens were conditioned at 22°C with a humidity of 50% for 48 h before conducting the tests. The impact test was conducted using the Gotech Impactor instrument [24]. The tensile test for the composites was carried out using the UTM, following the standard test method ASTM D3039. The crosshead movement was set at 0.02 mm per minute to ensure consistent testing conditions [25]. The flexural characteristics of the test specimens were assessed in accordance with ASTM D790, utilizing the UTM. The specimens were supported at both ends during the test, and a load was applied to the center until failure occurred, at a predetermined rate. The crosshead speed was set at 1 mm/min [25].

3 Results and Discussion

3.1 Density Testing

Density is one of the crucial parameters in characterizing the physical properties of fiberboard material. Density is the ratio of mass to volume, thereby illustrating the amount of substance mass per unit volume. It can depict the mechanical characteristics inherent in fiberboard, thus providing an initial overview of the material's mechanical properties. The results of the density testing conducted are displayed in Fig. 1.

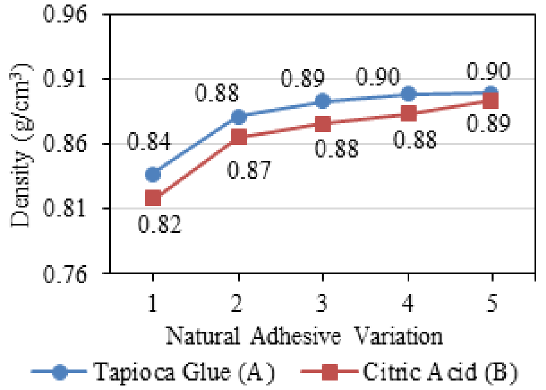

Fig. 1. Density of fiberboard composites from corn cob and coconut fibers were prepared using tapioca glue and citric acid.

Based on Fig. 1, the density progression in sample A was as follows: A1 through A5 at 0.837, 0.882, 0.893, 0.899, and 0.900 g/cm³, respectively. For sample B, the densities were lower, ranging from 0.816 g/cm³ in B1 to 0.894 g/cm³ in B5.

Tapioca glue, being composed of modified starches, tends to have larger polysaccharide chains compared to the relatively small organic molecule of citric acid [26]. Polysaccharides, with their plentiful hydroxyl groups, function as linkers in establishing hydrogen bonds within composites. These hydrogen bonds, recognized for their robustness and adaptability, undergo denser compression when subjected to pressure [27]. The stronger bonding and subsequent higher density of fiberboards made with tapioca glue can be attributed to the adhesive properties of the glue. These properties enable better adhesion between the fibers, leading to a tighter packing arrangement and consequently a higher density [26].

The observed trend indicates that the density increases with higher concentrations of adhesive in both A and B series, with A5 and B5 showing the highest densities due to the largest adhesive content. This highlights the significant impact of adhesive type and quantity on the density of the fiberboard. Interestingly, the fiberboards made with tapioca flour adhesive consistently exhibited slightly higher densities compared to those made with citric acid, suggesting differences in the adhesive properties' influence on the material density.

The highest densities recorded, particularly in A5 and B5, demonstrate the role of adhesives in enhancing the composite density. The study by Malau et al. [28] supports this finding, indicating the crucial role of adhesive type and composition in determining the characteristics of the particle board. Similarly, Kosim et al. [29] found that fiberboards made with coconut fiber and banana stem using synthetic PVA adhesive achieved a maximum density of 0.74 g/cm³, fulfilling the SNI 03-02105-2006 standard. This comparison underscores that the fiberboards in our study, with their higher densities, surpass the standards set for boards made with synthetic PVA adhesive.

Conforming to the Japanese Industrial Standard (JIS) A 5905: 2003, the composite fiberboards, especially those in the higher density range like A5 and B5, qualify as "hard boards." This compliance is significant as it demonstrates the potential of using natural matrices with corn cob and coconut fiber in producing fiberboards that meet rigorous industrial standards.

3.2 Porosity Testing

Porosity can be described as the ratio of the pore volume to the total volume of the material, expressed as a percentage. It indicates the extent to which the fiberboard consists of empty spaces or pores relative to the overall volume of the material. The porosity of the manufactured fiberboard is depicted in Fig. 2.

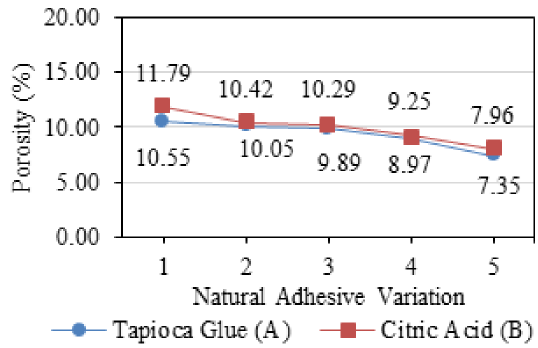

Fig. 2. Porosity of fiberboard composites from corn cob and coconut fiber using tapioca glue vs. citric acid.

Fig. 2 illustrates the porosity of the composite fiberboard, varying in composition with natural adhesive masses (tapioca flour and citric acid) combined with corn cob and coconut fiber. Composition A1 through A5 exhibit porosity levels of 10.55%, 10.05%, 9.89%, 8.97%, and 7.34%, respectively. Fiberboards created with citric acid adhesive showed slightly higher porosity levels compared to those with tapioca flour adhesive. The porosity for composition B1 trough B5 is 11.79%, 10.42%, 10.22%, 9.25%, and 7.96%, respectively. The highest porosity value observed in fiberboard with tapioca glue was in composition A1 (10.55%), while the lowest porosity was found in composition A5 (7.35%), with a standard deviation of 1.263. Similarly, the highest porosity value in fiberboard with citric acid was also found in B1 (11.79%), and the lowest in B5 (7.96%), with a standard deviation of 1.429, which could be due to the higher amount of adhesive, resulting in a matrix with fewer open pores.

The difference in porosity between compositions A (tapioca glue) and B (citric acid) can be attributed to differences in their chemical compositions and the interaction with the fibers [30]. Tapioca glue, being denser and more cohesive, likely forms stronger bonds with the fibers, resulting in a more compact structure with fewer open pores. Additionally, tapioca glue may have better affinity for the fibers, allowing for better penetration and adhesion compared to citric acid. As a result, the composite fiberboards using tapioca glue exhibit lower porosity levels compared to those using citric acid.

Previous research on fiberboard using citric acid as an adhesive, conducted by Aini and Widyorini [31] with snake fruit stem, produced fiberboard with similar porosity characteristics, around 8.00%. Furthermore, an increase in citric acid also helps block water ingress, contributing to a decrease in porosity. In addition, Waryati et al. [12] studied the production of composite fiberboard as a noise insulator, using tapioca flour adhesive and coconut fiber. This research indicated that the produced fiberboard had high water absorption and large pores. This is attributed to the hygroscopic nature of coconut fiber, allowing efficient water absorption into the material. Tapioca flour, used as an adhesive, also exhibited good water distribution properties, thereby enhancing water absorption [32]. From these studies, it is understood that fiberboards made using a combination of coconut fiber and corn cobs with natural adhesives resulted in high porosity because of the hygroscopic nature of the materials used. Additionally, a possible factor could be the insufficient amount of adhesive, leading to a less dense matrix. This results in the composite fiberboard having numerous open pores during the molding process.

Based on the density results presented in the previous subsection, it is evident that as the density of a fiberboard increases, its porosity tends to decrease [33]. This phenomenon stems from the fundamental principle that a higher density implies fewer void spaces or pores between the particles as they are packed more closely together. As a result, the decrease in porosity leads to a denser and more compact fiberboard structure. Conversely, lower density fiberboards exhibit higher porosity due to the presence of more open spaces within their structure [34].

3.3 Impact Strength Analysis

Impact testing was conducted to determine the toughness of the sample under dynamic loading, thereby ascertaining whether the material being tested is brittle or strong. The results of the impact strength test for the produced composites are displayed in Fig. 3.

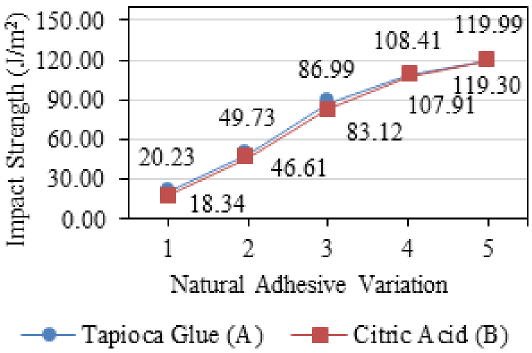

Fig. 3. Impact strength of fiberboard composites from corn cob and coconut fiber using tapioca glue vs. citric acid.

Fig. 3 displays the impact strength of fiberboard across various compositions. For the series using tapioca glue as adhesive, the impact strengths are as follows: A1 to A5 record 20.23, 49.73, 86.99, 108.41, and 119.99 J/m², respectively. In contrast, the series with citric acid adhesive, B1 to B5, show slightly lower values: 18.34, 46.61, 83.12, 107.91, and 119.30 J/m², respectively. Notably, the highest impact strength is observed in both A5 and B5 compositions. This trend indicates that the impact strength increased linearly with the addition of more adhesive to the matrix. The adhesive strengthened the bonds within the composite, as evidenced by the increased fiberboard density. These stronger bonds contribute to improved mechanical properties, showing a direct influence of the adhesive composition on the impact strength of the fiberboard. Similar findings were reported in a study by Rafi [35], who observed that increasing the amount of tapioca glue in fiberboards made from recycled newspapers enhanced the material's mechanical properties. Significant improvements were noted in mechanical tests like bending and impact strength, highlighting the crucial role of adhesive quantity in influencing the material's mechanical characteristics.

3.4 Tensile Strength Analysis

The tensile strength test is a mechanical property evaluation of materials, aiming to determine the tensile strength of each sample by observing the maximum tensile load sustained. The results obtained are presented in Fig. 4.

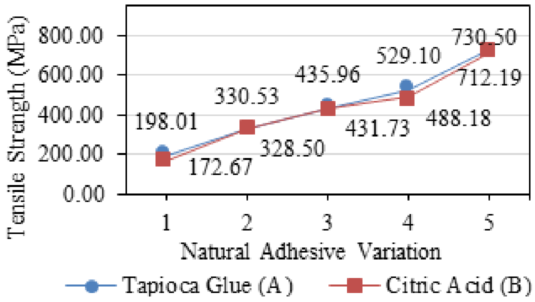

Fig. 4. Tensile strength of fiberboard composites from corn cob and coconut fiber using tapioca glue vs. citric acid.

Fig. 4 illustrates the tensile strength results for fiberboard samples A1 to A5, which were 198.01, 330.53, 435.96, 529.10, and 730.50 MPa, respectively. In compositions using citric acid as an adhesive, the values were slightly lower, with compositions B1–B5 showing tensile strengths of 172.67, 328.50, 431.73, 488.18, and 712.19 MPa, respectively. The highest tensile strength for each type of natural adhesive was observed in samples A5 and B5, which contained a greater proportion of the adhesive. This indicates a linear increase in tensile strength with the addition of more adhesive to the matrix. The increase is likely due to the improvement in the material's physical properties with the use of more natural adhesive. The study by Gumowska and Kowaluk [36] supports the findings of this research, demonstrating that increasing the content of natural binders such as starch in fiberboards significantly enhances their mechanical properties. This parallels the observed trend in our study, where higher proportions of natural adhesive, specifically citric acid, correlated with increased tensile strength in the fiberboard samples. The fiberboard manufactured in this study can be classified as High-Density Fiberboard (HDF) based on the tensile strength values observed. These values, ranging from 172.67 MPa to 730.50 MPa, indicate a high level of strength and density characteristic of HDF, a type of fiberboard known for its closely packed wood fibers and superior mechanical properties.

3.5 Flexural Strength Analysis

The flexural strength test was designed to determine the resistance of the composite to loading at three points of bending, and to assess the elasticity of the composite. The results of this strength test are presented in Fig. 5.

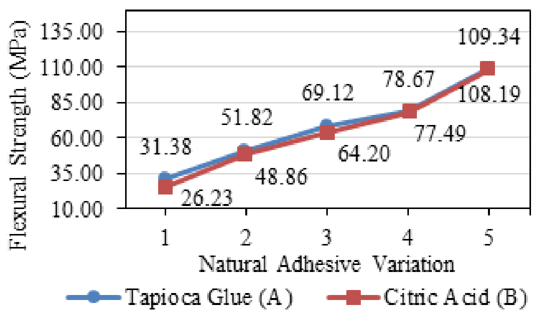

Fig. 5. Flexural strength of fiberboard composites from corn cob and coconut fiber using tapioca glue vs. citric acid.

Based on Fig. 5, samples A1 to A5, using tapioca glue as adhesive, exhibited flexural strengths of 31.38, 51.82, 69.12, 78.67, and 109.34 MPa, respectively. Overall, these results are higher compared to fiberboards with citric acid adhesive, where samples B1 to B5 showed flexural strengths of 26.23, 48.86, 64.20, 77.49, and 108.19 MPa, respectively. The relationship observed in the graph indicates that the flexural strength increased linearly with the addition of the adhesive to the composite matrix.

This increase could also be due to the improvement in the physical properties of the material associated with the increased use of natural adhesives. This trend is further supported by the research of Tisserat et al. [37], who investigated the use of Distillers Dried Grains with Soluble (DDGS) as a bio-based adhesive combined with Paulownia Wood (PW) in fiberboard production. Tisserat et al. [22] found that composites containing 50% DDGS and 50% PW exhibited optimal flexural properties. This finding is consistent with our observations, where a higher proportion of natural adhesive in the matrix led to increased flexural strength. The parallel outcomes from both studies highlight the efficacy of natural adhesives in enhancing the mechanical properties of fiberboards and suggest a broader applicability of various bio-based resins in the production of eco-friendly and high-performance fiberboards.

The relationship between flexural strength and impact strength in fiberboard compositions shows that as the flexural strength increases, the impact strength also increases [38]. This is because of several key reasons. Firstly, the adhesive in the fiberboard matrix enhances cohesion, making the material more strong against bending forces, which increases flexural strength. This structural stability also helps the material absorb more energy upon impact, boosting impact strength. Secondly, the reinforced matrix spreads stresses more evenly, reducing the risk of localized stress concentrations that can cause early failure. This even stress distribution contributes to both higher flexural and impact strengths. Finally, the adhesive reinforcement strengthened the fiberboard against bending and impact forces, further enhancing the overall structure.

Fig. 6 shows the appearance of manufactured fiberboards. The color of the fiberboard with tapioca glue was brighter than that with citric acid. This difference is because the color and chemical properties of the adhesives affect how they interact with the fibers in the fiberboard, influencing the final appearance.

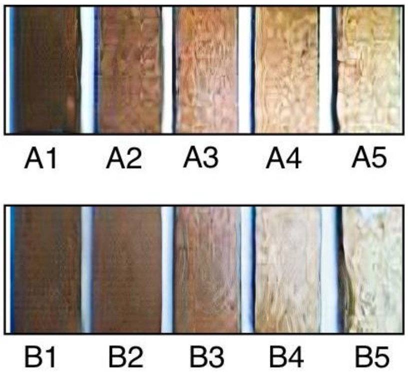

Fig. 6. Fiberboard composites from corn cob and coconut fiber using tapioca glue vs. citric acid.

Table 1 compares the mechanical and physical properties of various fiberboards fabricated from different materials. Some data were not provided because of the limited information. For instance, only one density value is available: 1.23 g/cm³ for the cellulose fiber composite, which is slightly higher than our study's findings. However, our study excels in both tensile and flexural strength, indicating the promising potential of fiberboards made from corn cob and coconut fiber.

Table 1. Comparative test with other composite

Composites	Comparative test					References
	Density (g/cm^3)	Porosity (%)	Impact strength (J/m^2)	Tensile strength (MPa)	Flexural strength (MPa)	
Cellulose/sugarcane bagasse/resin	NA	NA	NA	3.10	5.10	[39]
Cellulose fiber extracted from *Syagrus romanzoffiana*	1.23	NA	NA	671	NA	[40]
Sisal fiber reinforced wheat straw cellulose	NA	NA	NA	30.33	56.83	[41]
Fiberboard from corn cob and coconut fiber	0.90	7.35	199.99	730.50	109.34	This study

*NA= Not available.

4 Conclusion

In the research conducted on composite fiberboards made from varying mass ratios of corn cob and coconut fiber with natural adhesives, several key findings emerged. The study concluded that this combination produces a viable composite fiberboard material, capable of serving as a wood substitute. This material successfully meets the standards set by the JIS A 5095:2003, classifying it under the "hard board" category, thanks to its proven physical and mechanical properties.

The research highlighted that the most effective mass composition ratio for natural adhesives, such as tapioca glue and citric acid, was 26%. This specific ratio was found to enhance the overall physical and mechanical attributes of the composite fiberboard, especially in versions using tapioca glue. Comparative analysis revealed that tapioca glue has a slight edge over citric acid in terms of physical and mechanical properties. In terms of specific outcomes, the testing showed that sample A5, which utilized tapioca glue in the matrix of coconut palm frond fibers, achieved the best results. This sample demonstrated the highest density at 0.90 g/cm³, the lowest porosity at 7.35%, along with optimal impact strength at 119.99 J/m², a tensile strength of 730.50 MPa, and a flexural strength of 109.34 MPa.

Even if the research product meets JIS standards, the use of conventional wood in the domestic industry still dominates the industry. This is because the development of wood substitute composites often requires lengthier treatment compared to traditional wood, impacting their economic viability. Industries and factories tend to prioritize more cost-effective materials for their products. However, ongoing research on alternative fiberboards must persist to create high-quality economically feasible composites for the future.

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