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Utilization of Moringa Fruit Skin Waste and Wood Sawdust as Hybrid Composite Boards with Polyester Resin Matrix

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Abstract

Environmental damage, previously considered a local problem, has now developed into a global issue, with waste becoming an increasingly pressing issue, especially in developing countries. Inadequate waste management has the potential to cause serious impacts on environmental sustainability and human health. One type of waste that has not been optimally utilized is moringa fruit peel waste and sawdust. This waste often causes soil and air pollution if left to pile up and be burned. Therefore, this study aims to develop a Hybrid composite that combines moringa fruit peel waste and sawdust as a valuable alternative solution. This study uses an experimental approach in the laboratory with variations in waste composition (FSF 15%: WS 5%: PR 80%), (FSF 20%: WS 10%: PR 70%), (FSF 25%: WS 15%: PR 60%) and a composite board thickness of 1 cm. Testing parameters include tensile tests, compression tests, and water absorption. The tensile test results showed that the composition of 15% Moringa fruit peel fiber and 5% wood sawdust produced the highest tensile strength of 13.622 MPa due to the optimum condition of the reinforcing fraction, where the Polyester Resin matrix was able to wet the fiber evenly and form a strong interfacial bond so that stress transfer took place effectively during tensile loading. The compression test showed that the composition of 20% Moringa fruit peel fiber and 10% wood sawdust produced the highest compressive strength of 25.527 MPa due to the homogeneous fiber distribution and optimal interfacial bond between the reinforcement and the Polyester Resin matrix. The results of the water absorption test showed that the composition of 25% Moringa fruit peel fiber and 15% wood sawdust had the lowest or most optimal water absorption of 1.8% because the increase in the reinforcing fraction produced a denser and more homogeneous structure, thereby reducing porosity and limiting water entry.

Keywords: Moringa Rind; Hybrid Composite; Natural Fiber; Sawdust

Abstrak

Kerusakan lingkungan hidup yang sebelumnya dianggap sebagai masalah lokal kini telah berkembang menjadi isu global, dengan limbah menjadi salah satu masalah yang semakin mendesak terutama di negara berkembang. Pengelolaan limbah yang tidak memadai berpotensi menimbulkan dampak serius terhadap kelestarian lingkungan dan Kesehatan manusia. Salah satu jenis limbah yang belum dimanfaatkan secara optimal ialah limbah kulit buah kelor dan serbuk gergaji kayu. Limbah ini sering kali menimbulkan pencemaran tanah dan udara apabila dibiarkan menumpuk dan dibakar. Oleh karena itu, penelitian ini bertujuan untuk mengembangkan komposit *Hybrid* yang menggabungkan limbah kulit buah kelor dan serbuk gergaji kayu sebagai solusi alternatif yang berniali guna. Penelitian ini menggunakan pendekatan eksperimen di laboratorium dengan variasi komposisi limbah (FSF 15%: WS 5%: PR 80%), (FSF 20%: WS 10%: PR 70%), (FSF 25%: WS 15%: PR 60%)serta ketabalan papan komposit 1 cm. Parameter pengujian meliputi uji tarik, uji tekan, dan daya serap air. Hasil uji tarik menunjukan bahwa komposisi serat kulit buah kelor 15% dan serbuk gergaji kayu 5% menghasilkan kekuatan tarik tertinggi sebesar 13,622 MPa dikarenakan kondisi fraksi penguat yang optimum, dimana matriks *Resin Polyester* mampu membasahi serat secara merata dan membentuk ikatan antar muka yang kuat sehingga transfer tegangan berlangsung efektif saat pembebanan tarik. Uji tekan memperlihatkan bahwa komposisi serat kulit buah kelor 20% dan serbuk gergaji kayu 10% menghasilkan kekuatan tekan tertinggi sebesar 25,527 MPa disebabkan oleh distribusi serat homogen dan ikatan antarmuka yang optimal antara penguat dan matriks *Resin Polyeseter*. Hasil uji daya serap air menunjukan komposis serat kulit buah kelor 25% dan serbuk gergaji kayu 15% memiliki daya serap air yang paling rendah atau yang paling optimal yaitu sebesar 1,8% karena peningkatan fraksi penguat menghasilkan struktur yang lebih rapat dan homogen, sehingga mengurangi porositas dan membatasi jalur masuk air.

Kata kunci: Kulit Buah Kelor; Komposit *Hybrid*; Serat Alam; Serbuk Gergaji Kayu

1. Introduction

Environmental damage, which was previously considered a local issue within a country, has now spread and become a global issue [1]. The problem of waste is growing rapidly in developing countries, where the amount of waste produced is increasing rapidly [2]. Several environmental issues have attracted attention and scrutiny, such as air, soil, and water pollution, which are caused by the increasing amount of waste day by day [3]. Population growth has contributed to an increase in the volume of waste or garbage produced. Waste that is not managed properly can pose serious dangers to both environmental sustainability and health [4]. The issue of waste or garbage management is a matter of high urgency in Indonesia, and it is a difficult task for the government [5]. Waste from various communities, both from households and industries, often causes environmental pollution [6]. Waste is the residue of human activities in utilizing nature that is considered useless and is therefore treated as garbage [7]. It is important to understand that waste can be divided into two types: recyclable waste and non-recyclable waste [8]. One type of household and furniture industry waste that is still not properly managed is moringa fruit peel and sawdust, the use of which is still very limited [9]. This natural fiber waste is often left to pile up or burned, which can cause soil and air pollution [10]. Therefore, there is a need for processing that can give this natural fiber waste a good value [11]. One of the developments in renewable resources is composite products [12]. Moringa fruit peel and sawdust waste can be combined into a hybrid composite [13]. Hybrid composites are materials that combine two or more types of fibers reinforced by a matrix, marking an advancement in composite technology [14]. One of the materials that make up the composite acts as a binder, while the other material acts as a reinforcement or filler that provides additional strength to the material [15]. By utilizing moringa fruit skin natural fiber waste and sawdust as reinforcing materials for hybrid composites, it is hoped that the environmental impact can be reduced and useful materials can be produced [16]. The availability of these two materials has not been optimally utilized. The selection of moringa fruit peel waste and sawdust as reinforcing materials for hybrid composites is based on material characteristics and sustainability aspects.

The development of natural fiber-based materials has increased significantly in many industries due to the need to preserve the environment [17]. The use of synthetic fibers has begun to be abandoned, while natural fibers have regained attention as composite reinforcing materials because they are lightweight, environmentally friendly, and have relatively lower production costs [18]. The reinforcing materials commonly used so far are carbon, glass fibers, and ceramics [19]. The use of natural fibers as composite reinforcing components has begun to attract interest because of the high strength and stiffness of the fibers and their resistance to corrosion [20]. In addition, the use of natural fibers will result in composite products that are renewable, sustainable, and environmentally friendly because they do not produce waste that damages the environment [21].. Various studies have been conducted using natural fibers such as jute [22], flax [23], sisal [24], kenaf [25], banana [26], pineapple [15], and coconut fiber [27] as raw materials for manufacturing composite boards. However, there are still many types of fibers that have not been optimally utilized, one of which is moringa fruit peel waste and sawdust. This research was conducted with the aim of utilizing this waste as raw material for making hybrid composite boards as a valuable alternative solution.

2. Material and Method

This research is a pure laboratory experiment involving the treatment of research objects. The parameter for the success of this research is the production of composite boards made from natural fibers. To achieve this success, this research uses three main variables. First, the control variable, which is the ratio of moringa fruit skin fiber (FSF), wood sawdust (WS), and polyester resin (PR) with variations of (FSF 15%: WS 5%: PR 80%), (FSF 20%: WS 10%: PR 70%), (FSF 25%: WS 15%: PR 60%). Second, the independent variable, which is the thickness of the composite board used, namely 1 cm. Third, the dependent variable is the mechanical and physical properties of the composite board, which include tensile testing [28], compression testing, and water absorption testing. This research was conducted at the Science Laboratory of Muhammadiyah University Maumere for the process of making composite board samples and conducting water absorption tests, while tensile and compression tests were conducted at the Science Laboratory of Muhammadiyah University Surakarta.

2.1. Tools and Materials

Figure 1 shows the materials that will be used in this research, the main materials used in this study were moringa fruit peel waste and sawdust as composite reinforcements, polyester resin and MEKPO catalyst as the composite matrix or binder, and NaOH to remove impurities from the fibers. The tools used were silicone molds as a place to mold samples, beakers to mix natural fibers and polyester resin, digital scales to weigh natural fibers and resin according to the specified composition, a mixer to mix the resin with the filler to make it homogeneous, and a Universal Testing Machine (UTM) to test tensile and compressive strength.

(a) **(b)**

(c)

Figure 1. (a) Wood Sawdust, (b) Moringa Fruit Skin Fiber, (c) Unsaturated Polyester Resin

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2.2. Research Flowchart

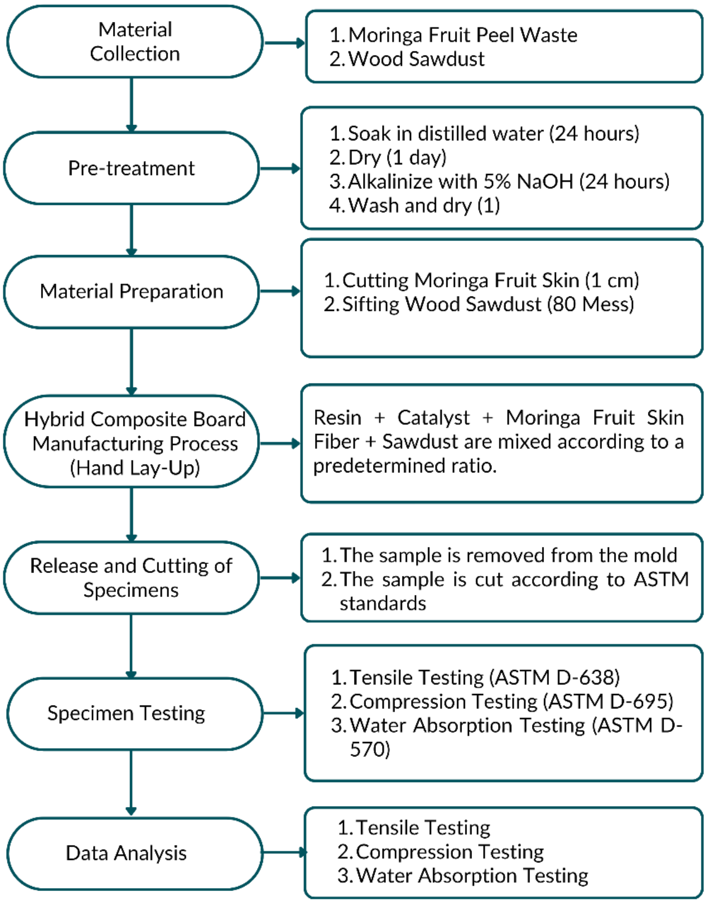

Figure 2. Research Flowchart

3. Results and Discussion

3.1. Tensile Testing

Tensile testing is a mechanical testing method that aims to determine the ability of a material to withstand the tensile force applied until the material breaks or snaps [29]. Through this tensile testing, information about the maximum tensile strength can be obtained [30]. This tensile test uses the ASTM D-638 standard, which is specifically used to test polymer-based composite materials to obtain results [28]. The tensile testing process on the specimen can be seen in Figure 3.

Figure 3. Tensile testing

From the tensile testing that has been carried out, data on tensile strength for various material compositions has been obtained. This shows that there are differences in tensile strength influenced by the ratio of moringa fruit skin fibers, sawdust, and Hybrid Unsaturated Polyester Resin used. Complete data on the tensile strength of each composition is shown in Table 1 and Figure 4.

Table 1. Tensile Strength Test Results of Moringa Fruit Skin Fiber and Sawdust Composites

No.	Fraction Volume (%)	Displacement (mm/min)	Load (kN/s)	Tension (MPa)
1.	Moringa Fruit Skin Fiber (FSF) 15%, Wood Sawdust (WS) 5%	10	10	13,622
2.	Moringa Fruit Skin Fiber (FSF) 20%, Wood Sawdust (WS) 10%	10	10	13,455
3.	Moringa Fruit Skin Fiber (FSF) 25%, Wood Sawdust (WS) 15%	10	10	12,294

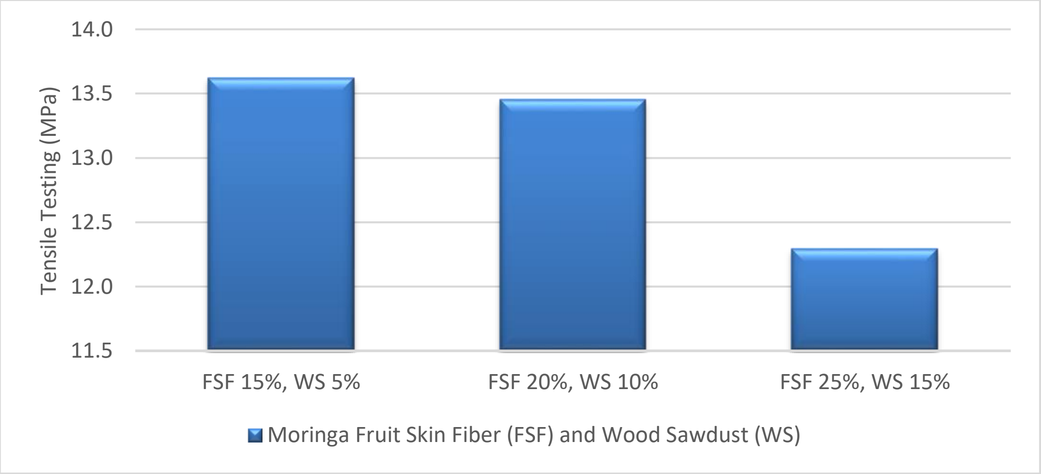

Figure 4. Tensile Strength Graph

Based on the tensile test data shown in Table 1 and Figure 4, the highest tensile strength value was obtained in the composition of 15% moringa fruit skin fiber (FSF) and 5% Wood Sawdust (WS), which was 13.622 MPa. Conversely, the lowest tensile strength value was found in the composition of 25% moringa fruit skin fiber (FSF) and 15% wood sawdust (WS), with a value of 12.296 MPa. Meanwhile, in the composition of 20% moringa fruit skin fiber (FSF) and 10% wood sawdust (WS), a tensile strength value of 13.455 MPa was obtained. The high tensile strength value in the composition of 15% Moringa fruit peel fiber (FSF) and 5% wood sawdust (WS) indicates the optimum condition of the reinforcing fraction, where the Polyester resin matrix is able to wet the fiber evenly and form a strong interfacial bond so that stress transfer takes place effectively during tensile loading. On the other hand, in the composition with a reinforcing fraction of 25% Moringa fruit peel fiber (FSF) and 15% wood sawdus (WS), the decrease in tensile strength is thought to be caused by the limitations of the matrix in coating the surface of the fiber and reinforcing particles which triggers the formation of agglomeration, voids (Volids), and suboptimal interfacial bonds so that stress transfer becomes ineffective and the material is easier to experience Tensile failure. Meanwhile, the composition of 20% Moringa fruit peel fiber (FSF) and 10% wood sawdus (WS) still shows a relatively high tensile strength, but slightly lower than the optimum composition, which indicates that the reinforcing fraction is starting to approach the optimum limit and the positive effect of adding fiber is offset by the reduction in the matrix fraction and increasing the inhomogeneity of the composite structure. The results of this study show a higher tensile strength value compared to the study conducted by Primananda et. al., which reported a maximum tensile strength of 9.226 MPa [31], thus indicating that the combination of materials and compositions used in this study provides better mechanical properties.

3.2. Compression Testing

Compression testing is a mechanical test method used to determine the ability of a material to withstand compressive loads until it undergoes deformation or damage [32]. The amount of load per unit area applied until the test specimen collapses indicates the strength value of the material [33]. The purpose of this test is to obtain accurate data on the strength of the material being tested [34]. In this study, the compression test was conducted based on the ASTM D-695 standard [35]. The compression test process on the specimen can be seen in Figure 5.

(a) (b)

Figure 5. (a) Compression Testing, (b) Completion of Compression Testing

Compression test results show variations in compressive strength for each material composition. These differences are influenced by the ratio of moringa fruit skin fibers, sawdust, and unsaturated polyester resin used. Compressive strength data is shown in Table 2, while a comparison graph can be seen in Figure 6.

Table 2. Compressive Strength Test Results of Moringa Fruit Skin Fiber and Sawdust Composite

No.	Fraction Volume (%)	Displacement (mm/min)	Load (kN/s)	Tension (MPa)
1.	Moringa Fruit Skin Fiber (FSF) 15%, Wood Sawdust (WS) 5%	50	20	22,856
2.	Moringa Fruit Skin Fiber (FSF) 20%, Wood Sawdust (WS) 10%	50	20	25,527
3.	Moringa Fruit Skin Fiber (FSF) 25%, Wood Sawdust (WS) 15%	50	20	21,760

Based on the Compressive Strength Test results shown in Table 2 and Figure 6, a composition of 20% moringa fruit skin fiber (FSF) and 10% wood sawdust (WS) produced the highest compressive strength value of 25.527 MPa.

Meanwhile, the lowest value was recorded in the composition of 25% moringa fruit skin fiber (FSF) and 15% wood sawdust (WS), with a compressive strength of 21.760 MPa. The composition of 15% moringa fruit skin fiber (FSF) and 5% wood sawdust (WS) showed a compressive strength of 22.856 MPa. The highest strength in the composition of 20% moringa fruit skin fiber (FSF) and 10% wood sawdust (WS) is thought to be caused by homogeneous fiber distribution and optimal interfacial bonding between the reinforcement and the polyester resin matrix. Conversely, at a higher reinforcement fraction of 25% moringa fruit skin fiber (FSF) and 15% wood sawdust (WS), the decrease in compressive strength is likely due to particle agglomeration, reduced matrix, and increased porosity which weakens stress transfer. Furthermore, 15% moringa fruit skin fiber (FSF) and 5% wood sawdust (WS), which is thought to be caused by the relatively low reinforcement fraction so that the polyester resin is able to fill the voids optimally and form a denser composite structure. The results of this study show a higher compressive strength value compared to previous research conducted by Jayadin et al., which reported a maximum compressive strength of 8.23 MPa [36], thus indicating that the composition and reinforcement system used in this study are able to significantly increase the ability of the composite board to withstand compressive loads.

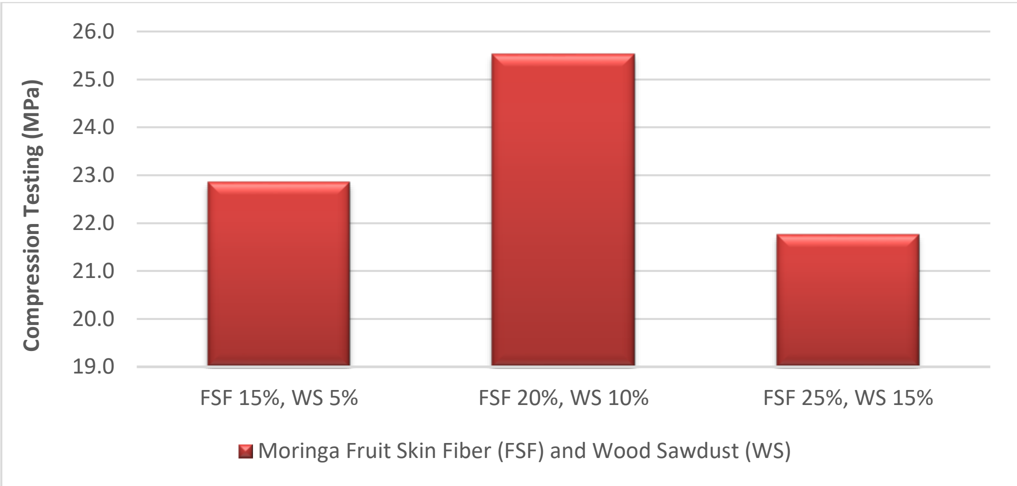

Figure 6. Tensile Strength Graph

3.3. Water Absorption

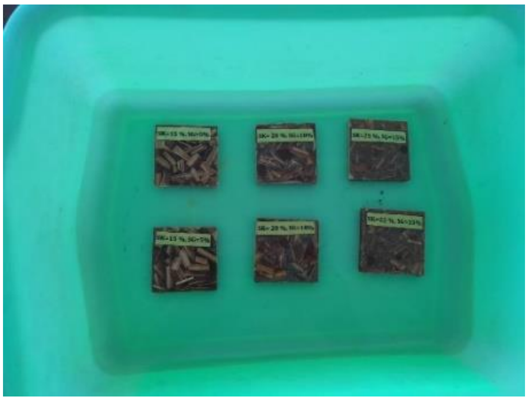

Figure 7. Water Absorption Test

Water Absorption Capacity testing aims to determine the material's resistance to water absorption up to its maximum limit [37]. The amount of empty space between particles that can hold air, the presence of channels on the surface of unsealed particles, and the depth of adhesive penetration into the particles are the main factors that affect the board's ability to absorb water [38]. The sample immersion process was carried out in water for 24 hours to determine changes in material characteristics after contact with water for a certain period of time [39]. In this study, Water Absorption testing was carried out based on the ASTM D-695 standard [40]. The Water Absorption testing process on the specimen can be seen in Figure 7.

Based on the results of water absorption tests, each sample with varying compositions of moringa fruit peel fiber, sawdust, and unsaturated polyester resin showed different levels of water absorption. This test was conducted to analyze the effect of the ratio of the three materials on the characteristics of the composite. The test results are shown in Table 3 and Figure 8.

Table 3. Water Absorption Test Results for Mango Fruit Skin Fiber and Sawdust Composites

No.	Fraction Volume (%)	Water Absorption (100%)
1.	Moringa Fruit Skin Fiber (FSF) 15%, Wood Sawdust (WS) 5%	2.1
2.	Moringa Fruit Skin Fiber (FSF) 20%, Wood Sawdust (WS) 10%	1.9
3.	Moringa Fruit Skin Fiber (FSF) 25%, Wood Sawdust (WS) 15%	1.8

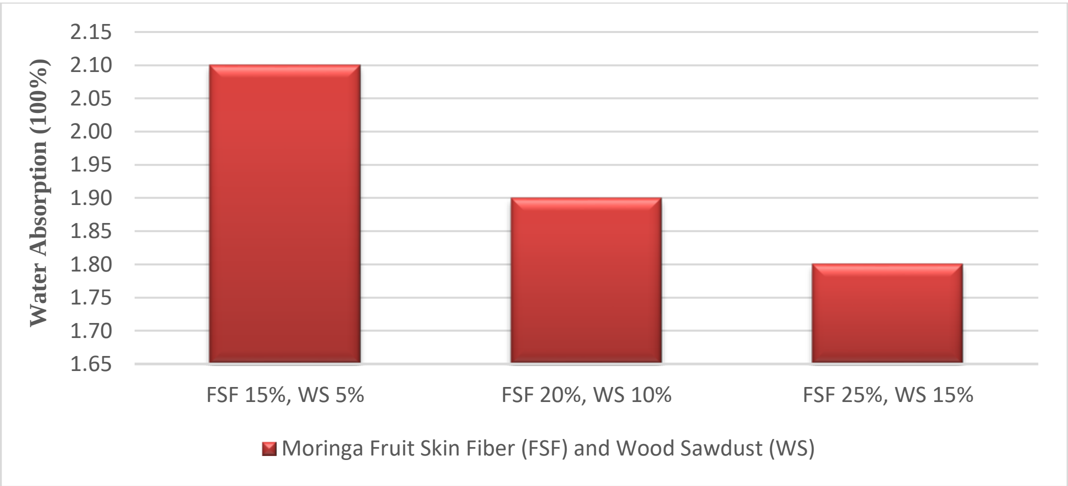

Figure 8. Graph of Water Absorption Results

The water absorption test results shown in Table 3 and Figure 8 indicate differences in water absorption levels for each variation in material composition. A composition of 15% moringa fruit skin fiber (FSF) and 5% Wood Sawdust (WS) had the highest water absorption value of 2.1%. This value decreases in the composition of 20% moringa fruit skin fiber (FSF) and 10% Wood Sawdust (WS) with a water absorption of 1.9%, and reaches the lowest value in the composition of 25% moringa fruit skin fiber (FSF) and 15% Wood Sawdust (WS) with a water absorption of 1.8%. Therefore, the composition of 25% moringa fruit skin fiber (FSF) and 15% wood sawdust (WS) is considered the most optimal composition in inhibiting water absorption. Thus, the composition of 25% moringa fruit peel fiber (KBK) and 15% sawdust (SG) is said to be the most optimal composition in inhibiting water absorption. The difference in water absorption values indicates that variations in reinforcement fractions affect the composite board in inhibiting water penetration. The highest water absorption in the composition of 15% moringa fruit skin fiber (FSF) and 5% wood sawdust (WS) is thought to be caused by a less dense composite structure and the presence of micro cavities that facilitate water diffusion into the matrix. The composition of 20% moringa fruit skin fiber (FSF) and 10% wood sawdust (WS) indicates an increase in structural density and reduced porosity as the reinforcement fraction increases. Conversely, the composition of 25% moringa fruit peel fiber (FSF) and 15% wood sawdust (WS) shows the lowest water absorption because the increase in the reinforcement fraction produces a denser and more homogeneous structure, thereby reducing porosity and limiting water entry. These results show better performance compared to previous research conducted by Haryanti et al. which reported the most optimal water absorption value of 26.16% [41], indicating that the material and composition used in this research are more effective in preventing water absorption.

4. Conclusion

Based on the results of mechanical and physical testing, it can be concluded that variations in the composition of moringa fruit skin fiber, sawdust, and unsaturated polyester resin affect the properties of the resulting composite. In the tensile test, a composition of 15% moringa fruit skin fiber and 5% sawdust produced the highest strength of 13.622 MPa, while a composition of 20% moringa fruit skin fiber and 10% sawdust showed the lowest value of 12.296 MPa. The compression test results showed a different trend, where the composition of 20% moringa fruit skin fiber and 10% sawdust provided the highest compression strength value of 25.527 MPa, while the lowest value was recorded in the composition of 25% moringa fruit skin fiber and 15% sawdust at 21.760 MPa. The water absorption test results showed that the lowest absorption value was 1.8%, which can be considered the most optimal composition for inhibiting water absorption. Conversely, the composition of 15% moringa fruit skin fiber and 5% sawdust had the highest water absorption of 2.1%.

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