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Hybrid Panel Board from Coconut Fibre & Fibre Glass

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Abstract

According to previous studies, panel board made from coconut fibre will more easily absorb water and cause the panel board material to expand. Meanwhile, fibreglass panel board have some drawbacks such as being too heavy to carry anywhere. In order to solve this issue, fibreglass and coconut fibre are used as the primary raw materials in hybrid panel board in place of standard panel board. It is expected that this project will improve the quality of the hybrid panel board on three main parameters; mechanical strength, water resistance, and soundproofing. 5 methods will be used to achieve the objective of this research. The first method of testing is the Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) to test the mechanical strength of panel boards. Next, a swelling test and water absorption test to assess the absorption ability. The last method is a soundproof test. For mechanical strength, a hybrid panel is better than a coconut fibre panel board and plywood but less than a fiberglass panel board. Furthermore, fiberglass has a lower percentage of water resistance than hybrid panel boards but better than coconut fibre and conventional panel boards. Last but not least, hybrid panel boards outperform plywood and coconut fibre panel boards but fall short of fibreglass panel boards.

1. Introduction

In recent years, the increasing emphasis on sustainable and environmentally friendly practices has prompted researchers and industry to investigate alternative materials for constructions [1]. As one of the largest consumers of natural resources, the construction industry contributes significantly to environmental degradation and CO2 emissions. To address these challenges, there is a growing demand for innovative and sustainable building materials that offer comparable or improved properties compared to conventional options. There are several scientific studies that have found natural materials that can be used in construction, such as coconut fiber, a natural material readily available in Malaysia. There are also non-natural materials that have better properties than natural materials, including fiberglass.

1.1 Coconut Fibre

Coconut fibre is a natural fiber from the husk of the coconut, containing 75% fiber and 25% coir pith [2]. Husks are often soaked, and coconut fibre is extracted for multiple uses. Coconut fiber is flexible and commonly used for cushions, mats, brushes, and padding. Coconut fibre is 30% fiber and 70% pith, with high lignin and phenolic content that reinforce plant tissues and defend against microbes [2]. Phenol compounds (PCs) are phytochemicals found in plants. They have many bioactive features and provide health benefits when consumed. Postharvest treatments can help maintain or enhance the levels of PCs in fruits and vegetables [3]. Coconut fibre is about 400 m wide and 103 m long. It is more flexible than oil palm bark fibers. Coconut is made up of water and copra in a hard shell covered by a fibrous husk, which protects it from damage.

1.2 Fiberglass

Fiberglass, also known as fiberglass-reinforced plastic, is highly versatile and durable material with many applications [4]. Incorporating fibreglass as the outer layer of a project brings significant advantages, such as enhanced durability, strength and protection against potential damage and external forces. Its high tensile strength and resistance to corrosion make it an ideal choice. Additionally, fiberglass has excellent insulation properties, reducing the risk of water absorption and ensuring the structure's longevity and structural integrity. Overall, the implementation of fiberglass aligns perfectly with the project's goals, enabling the creation of a durable and reliable structure that fulfills its intended purpose effectively.

Fiberglass is a versatile material that can be classified into different categories based on the types and propotions of raw materials used during manufacturing, such as A-glass and E-glass.A-glass is commonly used in the production of window panes, glass jars, and beverage and food containers, while E-glass finds applications in marine, aerospace, and industrial settings [5]. Fibreglass possesses exceptional mechanical strength, surpassing that of steel, and exhibits a small coefficient of linear expansion. It can be combined with synthetic resins and mineral matrices like cement, providing versatility in its applications [4]. Additionally, fibreglass demonstrates resistance to rot, decay, rodents, and insects, while also having low thermal conductivity and high dielectric permeability. These advantageous properties make fibreglass a durable and versatile material suitable for a wide range of applications, including construction and electromagnetic windows.

Additionally, coconut fiber is an ideal choice for panel board production due to its exceptional sturdiness, elasticity, and resistance to rot [4]. It can withstand external forces without breaking and ensures durability in humid environments. Its excellent flexural hardness allows panel boards to endure bending and stress. Fiberglass, on the other hand, offers unparalleled durability and can be molded into various shapes and sizes, making it versatile for panel board customization. It is recognized as a high-quality material with exceptional mechanical properties. Together, coconut fiber and fiberglass create panel boards that are strong, resilient, and long-lasting, suitable for diverse applications.

1.3 Problem statement

Panel board is a structural component used mostly in the production of furniture and for structural purposes in the construction of buildings. According to website sources, panel board prices increased to US$6.7 billion in 2022 and are expected to grow at a CAGR of 5.7% between 2023 and 2032. There are other alternatives that can be used to manufacture building products from organic and inorganic materials. Based on previous studies, coconut coir and fiberglass are among the most suitable materials for manufacturing panel board. However, a panel board made of one material has a clear weakness compared to a panel board made of two different materials. When using coconut fibre as the primary ingredient in manufacturing panel boards, there are several distinct feature or qualities of coconut fibre that are spcifically beneficial for panel board production. One of the properties is coconut fiber, which has an extreme lignin content that prevents water from destroying the polyacrylamide-protein matrix of plant cells [2] [6]. However, a construction product like panel board that uses coconut fiber is not a proper version of panel board. The reason is the characteristic that the panel can easily absorb water, which causes the panel to be weak. When using fiberglass as the main component,it has very high softening points and better resistance to fatigue and creep [7] [8]. Even though fiberglass is good for mechanical strength and water resistance, it still has flaws like being extravagant and having extreme bulk, making it inconvenient to transfer anywhere.

The purpose of hybrid panel boards is to make better panel boards and a more environmentally friendly product than coconut fiber and fiberglass panels themselves, and to measure hybrid panel board strength, water resistance, and soundproof properties. Coconut fiber is an ideal component for panel boards due to its resilient, non-decaying nature, attributed to its high lignin content. However, coconut fiber is unsuitable for use as a proper panel board due to its water-absorbing nature, making it weak. Nevertheless, fibreglass has high softening points, good heat absorption, and resistance to fatigue, but it is costly and bulky for transportation.

2. Materials and Methods

The research flow diagram for this work is depicted in Fig. 1. A multi-phase process is used to develop fiberglass and coconut fiber into the hybrid panel board. Phase 1involves preparing the samples, which includes layering, cutting and finishing the panel board. Phase 2 involves compacting fiberglass and coconut fiber to create samples

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of hybrid panel boards. In phase 3, comprehensive testing is performed on all samples to determine their mechanical strength, water resistance and soundproofing qualities.

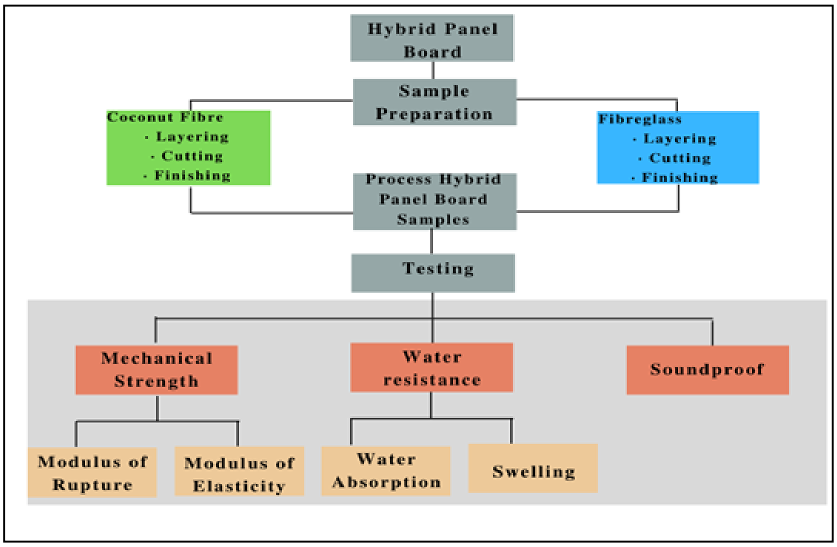


Fig. 1 *Research flow diagram*

2.1 Coconut Fibre Panel Board Process

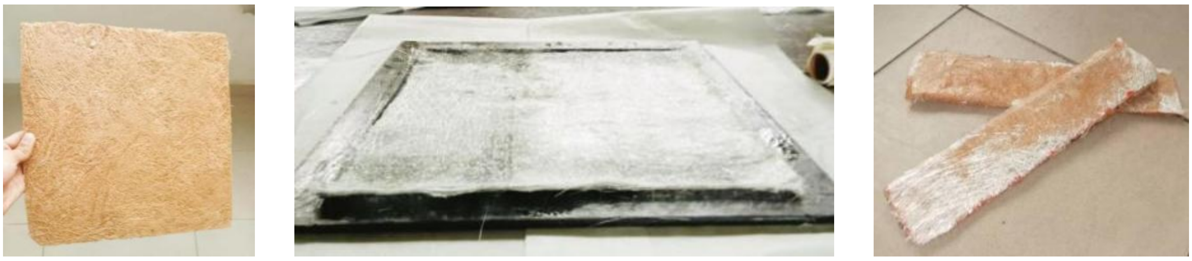
Coconut fibres were sieved using a sieve machine. After that, coconut fibre was weighed using a balance and then mixed well with urea glue according to 7: 3 ratio in a mould. Mixed coconut fibers were compacted with a hot press hydraulic machine at 80 degrees Celsius. Fig. 2 shows the panel board from the coconut fibre panel. Next, the panel board was cut into a sample size.

2.2 Fiberglass Panel Board

Fiberglass matt was cut out into the size of pile mould which is 300 mm x 300 mm. Then, resin and hardener were mixed well. After that, apply wax on the mould to prevent the fiberglass from sticking to the mould. Next, fibreglass was laid on the waxed mould. Pour down the mixture of the resin and spread it through the surface of the fibreglass with a brush. After allowing the fiberglass to dry, it was cut into sample sizes. Fig. 2 shows the sample of the fiberglass panel board.

2.3 Hybrid Panel Board

A sieve machine is used to sieve coconut coir. After that, a balance is used to weigh the coconut coir. With the aid of a hot press hydraulic equipment, the combined coconut coir is compacted. Fibreglass mats are cut to fit the pile mold's dimensions. Resin and hardener are then thoroughly combined. After that, cover the panel board with fiberglass on the outside and coconut fibre on the inside.



(a) (b) (c)

Fig. 2 *Panel Boards (a) a) Coconut fibre panel board; (b) Fiberglass fibre panel board; (c) Hybrid panel board*

2.4 Testing Method

Using MOE testing, it is possible to assess how conventional panel boards will behave when subjected to an axial stretching force for coconut fibre. The correlation between stress and strain in the specimen is associated with the modulus of elasticity, commonly known as Young's modulus. The modulus of rupture, alternatively known as the flexural modulus, quantifies the strength of the sample prior to failure under maximum stress. Fig. 3 illustrates the UTM Instron device, which can be utilized to directly determine the cohesive strength of the sample.

Fig. 3 *Universal Testing Machine*

$$\frac{water\ weight - dry\ weight}{dry\ weight} \times 100 \tag{1}$$

After that, water absorption tests will be undertaken on panel board samples to investigation the water absorption content of each panel board. This test will record weight readings before and after soaking in water for 24 hours. This test adopts an electronic weighing device to estimate the weight of the sample before and after soaking in water.

$$\frac{Volume}{Thickness\ before} - \frac{Volume}{Thickness\ after} \tag{2}$$

Besides that, the other test is the swelling thickness test. This test is to determine the expanded size of each sample panel board after being immersed for a certain time. A sample from each design will make a thick comparison. The panel board with a thicker increase will be considered to have low resistance to water and high-water absorption.

Lastly, finding the height of the sound frequency against the panel board is the aim or goal of the soundproof test. A microphone and a Sound Level Meter are the tools used. This will demonstrate that the sample panel board contains coconut fibre, fibreglass, and hybrid panel board, with the latter having the best sound absorption.

3. Results and Discussion

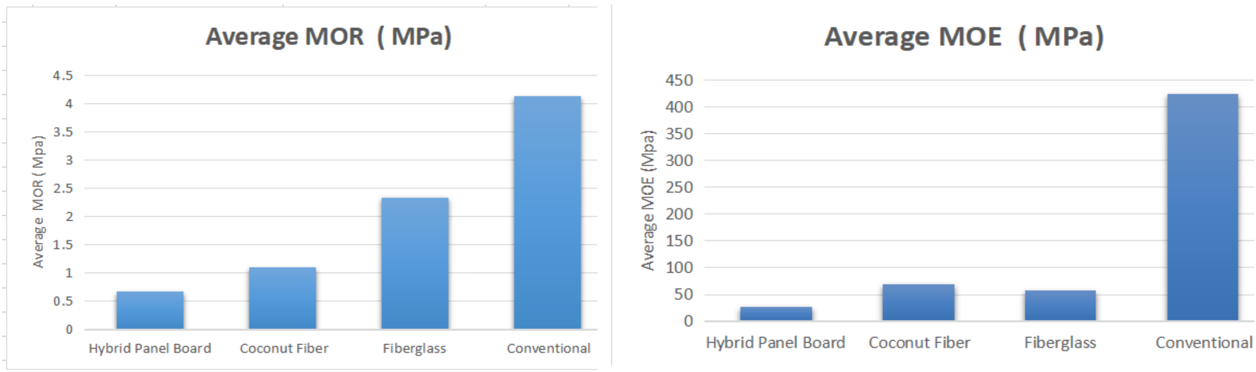
3.1 Modulus of Rupture

The Modulus of Rupture can be identified based on the average MOR graph as shown in Table 1 and Fig. 4. As for the test, Table 1 shows the maximum load that hybrid panel boards, conventional panel boards, fibreglass panel boards and coconut fibre panel boards can resist is 0.031 kN, 0.225 kN, 0.026 kN and 0.093 kN and there is a very notable difference between the hybrid panel boards, conventional panel boards, fibreglass panel boards and coconut fibre panel boards . The conventional panel board has the highest value of MOR which is 4.13 Mpa while the coconut fibre panel board is 1.10 Mpa, fiberglass panel board is 2.34 Mpa and hybrid panel board is 0.67 Mpa. The MOR value is a measure of a specimen's ultimate strength before it ruptures or breaks. The higher value of MOR indicates that the panel board requires more force to end it until it breaks compared to those panel boards with lower MOR value. The value strength of conventional panel boards is higher than value strength of coconut fibre panel boards, fibreglass panel boards and hybrid panel boards because conventional panel board have smaller particles than other panel boards. This is caused by smaller particles being more tightly packed, with fewer overlapping regions, resulting in homogeneous, uniform cells with fewer voids.

3.2 Modulus of Elasticity

The modulus of elasticity can be determined by analyzing the average MOE graph presented in Table 1 and Fig. 4. In this test, the hybrid panel boards, conventional panel boards, fibreglass panel boards, and coconut fibre panel boards demonstrated maximum resistance to MOE at 26.33 Mpa, 42.5 Mpa, 57.69 Mpa, and 69.26 Mpa, respectively. A higher MOE value indicates greater stiffness of the panel board. These values can be attributed to the lower inertial strength observed in hybrid panel boards compared to conventional panel boards, coconut fibre panel boards, and fiberglass panel boards.

Fig. 4 and Table 1 reveal that coconut fibre panel boards exhibit greater elasticity, requiring more force to deform. When considering panel boards, higher MOE values are preferable even when subjected to higher external forces.



(a) **(b)**

Fig. 4 *Graph a) Graph Modulus of Rupture and b) Modulus of Elasticity*

3.3 Water Absorption

Table 1 presents the outcomes of water absorption for various types of panel boards: hybrid panel board, coconut fiber panel board, fiberglass panel board, and conventional panel board. The comparison is made in terms of density and water absorption in relation to the conventional panel board. Fig. 5 illustrates the correlation between the density and water absorption of the panel board. The data reveals that the hybrid panel board exhibits the highest density value of 6240 kg/m3, followed by the conventional panel board, fiberglass panel board, and coconut fiber panel board. Their respective density values are 6240 kg/m3, 1070 kg/m3, 1450 kg/m3, and 5640 kg/m3. Concerning water absorption, the coconut fiber panel board demonstrates the highest average value of water absorption is 172.12 %, while the other panel boards exhibit a low average water absorption. The density of the panel board is a significant factor influencing water absorption. A higher density indicates a lower average for water absorption. Coir fiber, known for its high lignin content, helps control the water absorption effect [9]. Materials with greater porosity tend to absorb more water. A high-density panel board reduces porosity, minimizing water absorption and preventing swelling when immersed in water. In conclusion, a higher panel board density reduces water absorption when exposed to water, while lower density yields higher-thickness absoprtion. This analysis emphasizes the importance of panel board density in managing water absorption effects.

3.4 Thickness Swelling

Table 1 presents the outcomes of thickness swelling for various types of panel boards: hybrid panel board, coconut fiber panel board, fiberglass panel board, and conventional panel board. The comparison is made in terms of density and thickness swelling in relation to the conventional panel board. Fig. 5 illustrates the correlation between the density and thickness of swelling of the panel board. The data reveals that the hybrid panel board exhibits the highest density value of 6240 kg/m3, followed by the conventional panel board, fiberglass panel board, and coconut fiber panel board. Their respective density values are 6240 kg/m3, 1070 kg/m3, 1450 kg/m3, and 5640 kg/m3. Concerning thickness swelling, the coconut fiber panel board demonstrates the highest value of approximately 1%, while the other panel boards exhibit a negligible thickness swelling of 0 %. The density of the panel board is a significant factor influencing thickness swelling. A higher density indicates a lower propensity for swelling. Coir fiber, known for its high lignin content, helps control the swelling effect. Materials with greater porosity tend to absorb more water [9]. A high-density panel board reduces porosity, minimizing water absorption and preventing swelling when immersed in water [4]. In conclusion, a higher panel board density reduces the likelihood of swelling when exposed to water, while lower density yields higher-thickness swelling. This analysis emphasizes the importance of panel board density in managing swelling effects.

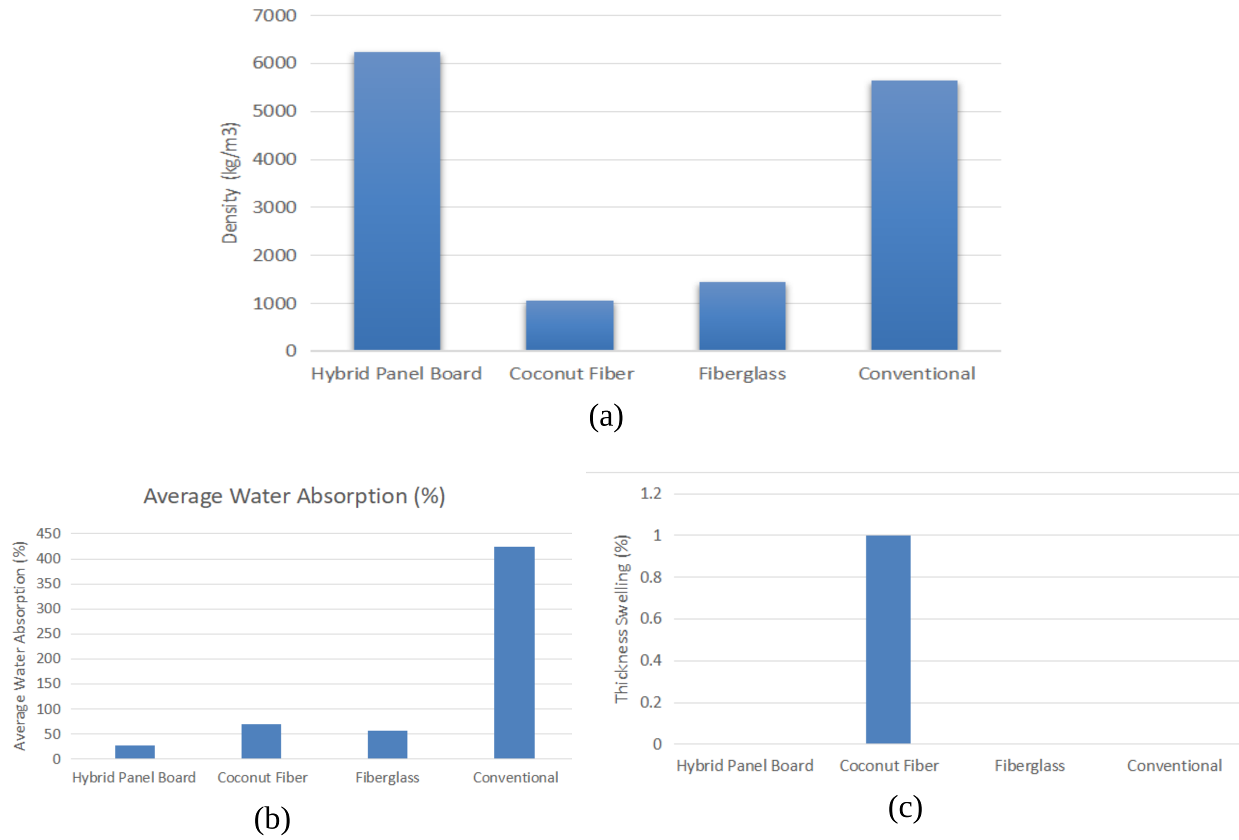


Fig. 5 *Graph a) Density, b) Water Absorption and c) Thickness Swelling Test Result*

3.5 Soundproof

Based on the panel board data tested in Table 1 and Fig. 6, the highest frequency reading obtained on the panel board is the reading of the coconut fiber panel board with a value of 67 Hz, while the lowest frequency reading is the reading of the fiberglass panel board with a value of 62 Hz. For the average frequency value for each panel tested, the values obtained on the fiberglass panel board, coconut fiber panel board, hybrid panel board and conventional panel board gave values of 62 Hz, 67 Hz, 55 Hz, and 60 Hz, respectively. This means that the soundproofing properties of hybrid panel board are the better and more effective than coconut fibre panel board, fiberglass panel board and conventional panel board.

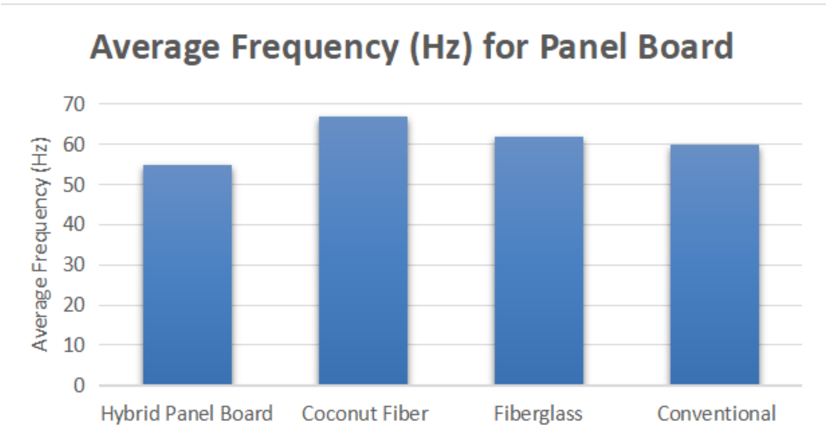


Fig. 6 *Soundproof Test Result*

Table 1 *Five Test Result of Samples*

Type of Panel Board	Density (kg/mm3)	Average MOR (MPa)	Average MOE (MPa)	Average Water Absorption (%)	Thickness Swelling	Type of Panel Board
Hybrid	6240	0.67	26.33	117.66	0	55
Coconut Fiber	1070	1.10	69.26	172.12	1.0	67
Fiberglass	1450	2.34	57.69	22.38	0	62
Conventional	5640	4.13	42.5	55.56	0	60

4. Conclusion

In conclusion, the analysis of the data highlights the significant advantages offered by hybrid panel boards compared to other options. They exhibit favorable values for MOE and MOR, making them suitable building materials. Moreover, the laboratory testing demonstrated that hybrid panels outperform other panels in terms of water absorption and sound insulation properties, which are crucial in the field of civil engineering, especially in Malaysia. It is recommended that the industry embraces and advances the use of hybrid panel boards to enhance competitiveness and sustainability. This adoption can lead to greener building products and lower manufacturing costs, driving innovation and optimizing processes in the construction industry. Overall, hybrid panel boards present a compelling solution for achieving strength, water resistance, and soundproofing in civil engineering, and their adoption holds great potential for industry growth.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: Study literature, method, data analysis, draft manuscript preparation, and finalized the manuscript: Muhammad Hazmie Heizran Ahmad Kamel, Muhammad Naufal Hazim Jalaluddin, Nur Muhamad Mohamad Sufian, Norhayati Ngadiman.

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