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ORIGINAL ARTICLE

Modifying bioproduct technology of Medium Density Fibreboard from the seaweed waste *Kappaphycus alvarezii* and *Gracilaria verrucosa*

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Abstract The effort to conserve Indonesian forest has become the main development priority which is indispensable to maintain the ecosystem balance, as well as thrive to preserve the use of timber wisely. Some alternative products, such as a composite board, are ideal to be developed as the alternative of timber products, as they have a main advantage of having various non-timber waste as the raw materials. One of examples of the timber utilization as the industrial raw material which have bright potential for both domestic and export marketing is the Medium Density Fibreboard (MDF) industry. The last few decades have shown that the need for MDF has been growing rapidly in Asia Pacific and Europe, recorded more than 15% growth rate per year. MDF is made of lignocellulose fibre combined with synthetic resins or other bondings which are appropriate for the high temperature's and pressure's treatment. The main component to fabricate MDF is lignocellulose which can be obtained from timber, straw, grass, farm/forest waste, industrial waste (timber, paper), and other fiber materials. Lignocellulose contains three main compositions: cellulose, hemicellulose, and lignin. The seaweed waste, namely *Kappaphycus alvarezii* and *Gracilaria verrucosa*, which experienced the carrageenan extraction and already contain sufficient lignocellulose as the raw material to manufacture MDF. Modifying bioproduct technology of MDF from the seaweed waste (*K. alvarezii* and *G. verrucosa*) is an advantageous alternative effort for the sake of both ecosystem balance and environmental friendly technological innovation.

Keywords Medium Density Fibreboard · Seaweed waste · *Kappaphycus alvarezii* · *Gracilaria verrucosa*

Introduction

Seaweed processing, as the alternative farming activity besides fishing, has been frequently conducted by the current Indonesia fishermen, even though the products are mostly in the forms of dry seaweed (raw material). Dry seaweed production in Indonesia, particularly *Kappaphycus alvarezii* and *Gracilaria verrucosa*, in 2010 is amounted for 800,000 ton/year and recorded as the 50% of world contributor, where 85% of the products are exported; after that, it is manufactured into food, health products, and cosmetics by the importers. Indonesia owns 34 seaweed processing industry to proceed the seaweed to be *carrageenan* so that seaweed waste utilization becomes the main focus. The produced waste is usually being accumulated at the landfill. Although it is not dangerous, the waste pile is more likely to cause pollution problems, particularly if the landfill is no longer able to accommodate the production waste. Afrianto and Liviawati (1993), Ilknur and Cirik (2004), and Basmal (2011) even mentioned that seaweed's benefits are not used only for food, but also as pharmaceutical products and industry's raw materials. Those need to be further explored, along with the benefit of seaweed waste as the alternative material to manufacture composite board.

Composite board is highly ideal to be developed as the replacement of timber products, as it has several advantages; namely because its raw material is obtained from

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various non-timber waste (Wulandari 2013). One of timber's utilizations as the industry's raw materials which own positive domestic marketing and export potential is the *Medium Density Fibreboard* (MDF). In these last 10 years, MDF consumption has been growing rapidly in Asia Pacific (recorded at 16–17%/year) and Europe (15%/year) (Effendi 2001). MDF is manufactured from lignocellulose fibre which is combined with synthetic resin and other forms of bonding appropriate for the high temperature's and pressure's treatment (Mahzan et al. 2011). Adhesive is an extremely important material in manufacturing composite products, because it can determine the product's quality (Sulastiningsih et al. 2013). Adhesive is one of the main, important materials, because it takes up 20–60% of all production cost in composite wood industry (Santoso 2012).

Luthfy's (1988) findings on the seaweed content from *K. alvarezii* reported that it contains 19.92% ash content, 2.80% protein, 1.78% fat, 7.02% crude fibre, and 64.8% carbohydrate which has the highest content in *K. alvarezii* seaweed. Carbohydrate contains lignocellulose which is a part of biomass originated from plants with lignin, cellulose, and hemicellulose as their main components (Wiratmaja et al. 2011). The previous study on *K. alvarezii* seaweed explained that cellulose is comprised of 17.47% of its content; while hemicellulose takes up 21.16% and lignin is recorded at 8.23% (Sintaria 2012). Lignocellulose materials can be processed into a product to replace solid wood, namely composite board. Composite board is a wood product fabricated from smaller pieces of materials which are glued together (Risnasari 2008). Some examples of composite boards are lamina board, particle board, and fibre board (Wulandari 2013). Fibre board is one of wood panel products generated from hot tempering of wood fibre or other lignocellulose materials with the main bonding originated from the related raw material or other material (particularly adhesive) in order to obtain a special characteristic. Fibreboard products have many types, one of them is called *Medium Density Fibreboard* (MDF) which is the wood panel product made of lignocellulose fibre with 0.4–0.8 g/cm^3 density (Maloney 1993).

Furniture using MDF is usually used for practical furniture which is mass-produced by factories. Knock-down system is used in almost all furniture industries using dowel (a block of wood or small plastic) or connecting bolt which enables the product to be disassembled and assembled easily. The story behind MDF is based on the sharp increase of industrial timber needs. It is indicated by the growing furniture industry and other industries which utilize timber as their raw material. Based on the previous statement, if timber as the raw material is not readily available (as the forests will definitely not grow wider), the industry will eventually suffer from bankruptcy. Therefore, processed wood is created in order to fulfill the timber needs for furniture industry.

All these while, MDF needs are still imported from Singapore, Taiwan, and Malaysia, recorded at 200,000–300,000 m^3/year. The increasing consumption of MDF is caused by the multi-purpose benefits, especially for interior needs. MDF is more flexible in use compared to plywood and particle board, which makes MDF viable as a replacement for both products in the future. Furthermore, MDF has homogeneous density and rigidity compared to the other fibreboards, thus, its usage is growing wider; namely furniture, moulding, interior, window frame, door skins, TV shelf, radio, and other decorative goods. Its production capacity tremendously increases particularly in Europe and in 2000; its production is projected to reach 20 million m^3. The countries which produced MDF are Italy, Germany, Spain, France, Portugal, and Britain (Effendi 2001).

Fibreboard production from the remaining wood production is one of the solutions to solve the wood scarcity nowadays, either as structural board's (construction board) or non-structural board's (interior and coating) raw materials. Those composite products consist of particle board, fibre board, OSB, comply, WPC, and other composite products (Hakim et al. 2011). In its production process, it generally uses sawdust from the trees; thus, it is correlated to the global environmental issue on the trees' crucial role as the O_2 source and CO_2 absorber (it is estimated that 18.35 billion ton of CO_2 is released every year).

Meanwhile, seaweed waste is also included in waste products category which contains lignocellulose. Therefore, it is interesting and beneficial to be examined, as well as utilized as the composite board, an alternative for the industry's raw material to be manufactured into panel products. Based on the statements above, it is necessary to study about the technological modification of seaweed waste as an alternative of sawdust in manufacturing high-quality and effective MDF, as well as an extremely beneficial effort for the sake of ecosystem balance and environmentally friendly technological innovation.

Materials and methods

Research design

This research is contained these following activities: bioproducts' technological modification test of MDF which is made of seaweed waste (*K. alvarezii* and *G. verrucosa*) by identifying both seaweed; fabricating MDF by utilizing seaweed waste (*K. alvarezii* and *G. verrucosa*), biological characteristic test; physical and mechanical test of the MDF made of the seaweed waste (*K. alvarezii* and *G.*

verrucosa). The experiment design used is Completely Randomized Design (RAL) with nine treatments and three replications, namely A: Treatment with 100% sawdust (control); B: Treatment with 100% *K. alvarezii*; C: Treatment with 100% *G. verrucosa*; D: Treatment with 75% sawdust and 20% *K. alvarezii*; E: Treatment with 75% sawdust and 25% *G. verrucosa*; F: Treatment with 50% sawdust and 50% *K. alvarezii*; G: Treatment with 50% sawdust and 50% *G. verrucosa*; H: Treatment with 25% sawdust and 75% *K. alvarezii*; I: Treatment with 25% sawdust and 75% *G. verrucosa*.

Preparation of seaweed

Seaweed waste, *K. alvarezii* and *G. verrucosa*, used are the remaining waste from the aquaculture pond's harvest or factory waste. Next, the repulping and washing process are conducted. The seaweed waste is being put inside a disentigrator (to stir and separate fibre) and then water is added until the seaweed is completely covered. The mix is then stirred for 20–25 min. The process is conducted in order to separate the seaweed from the dirt so that only pure seaweed fibre is obtained.

The next step is filtering and drying the seaweed. It is filtered with a special equipment to separate it from dirt and water, and then it is dried up naturally and by oven so that the water rate reaches 5–8%. During the MDF manufacture process, sawdust is added into the mix with seaweed waste and epoxy adhesive according to the treatment dose.

Production of Medium Density Fibreboard (MDF)

MDF manufacture is conducted by dry process, namely by using hot press. After mixing the raw material with the adhesive, hot pressing in 170 °C of temperature and 45 Pa bar of pressure is conducted for 25 min. The board size is 20 × 20 × 2 cm^3 with targeted density of 0.4–0.8 g/cm^3. Next, the conditioning process is conducted: the hot-pressed board is left inside the frame for 24 h so that the final fibreboard product is not bending. Then, a re-conditioning for 2 days is conducted to obtain a high quality fibre board (Hakim et al. 2011).

Density

Density (g/cm^3) was determined by dividing dry air test mass (g) to dry air test volume (cm^3).

Absorbability

Absorbability test is conducted along with thickness swelling test. Generally, the higher thickness swelling rate is, the higher water absorbability will be; and vice versa. According to JIS A 5908 (2003), water absorbability is not required. Water absorbability is tested by measuring MDF weight before and after it is being soaked for 24 h. Water absorbability can be calculated using the following formula:

$$(\mathrm{Wo} - \mathrm{W_1}) / \mathrm{W_1} \times 100\%$$

Notes Wo = Initial weight (gr); W_1 = Final weight after 24 h being soaked (gr)

Thickness swelling

The thickness swelling of particle board is one of the physical characteristics which determine the composite board used for interior and exterior. If the thickness swelling is high, it means that product's dimension stability is low; thus, the product cannot be used for exterior purpose and its mechanical characteristic shall decrease in a short period of time.

The thickness swelling test is conducted at the same time with the water absorbability test. The measured parameter is the additional length, width, and thickness of MDF before and after soaking it in the water for 24 h. The thickness swelling is calculated with the following formula:

$$\mathrm{P} = \frac{\mathrm{T_2} - \mathrm{T_1}}{\mathrm{T_1}} \times 100\%$$

Notes P = thickness and linier swelling (%); T_1 = initial thickness/length before being soaked (cm); T_2 = thickness/length after being soaked for 24 h (cm).

Modulus of elasticity

Modulus of elasticity (MOE) is the strength to endure the forces which bend the wood or endure dead load and live load, except for impact load. Modulus of Elasticity (MOE) tests the object's ability to withhold elasticity force. On this term, mechanical characteristic of the object is determined by the inclination rate to the straight line of load deflection. Therefore, MOE is calculated using this following formula:

$$MOE = \frac{PL^3}{4bh^3 \Delta Y}$$

Notes MOE = Modulus of Elasticity; PI = Threshold load (Kg); L = Object length (mm); b = Object width (mm); d = Object thickness (mm); Y = Center gradient on Threshold.

Modulus of rupture

In the modulus of rupture's test, MDF sample is being placed on two supports, and then a load is placed in the middle of the supports at constant loading rate. MDF is performed using *Universal Testing Machine* (UTM).

Internal Bond

Internal Bond is conducted by bonding two board surfaces to an iron block using epoxy adhesive for 24 h; then, the iron block is pulled in the reversed direction.

Edge screw holding

This test aims to find out the screws' pulling force which is tied to the edge of the board; the screw's diameter is 3.2 mm and it's 17 mm deep. After the screw is installed, it is pulled out at 2 mm/minute. The force needed to pull the screw out shows the MDF's strength at holding the screw.

Anti-termite attack test

Anti-Termite Attack test is conducted by baiting the termite and putting an MDF (which is mixed with anti-termite material) inside an empty aquarium; the aquarium is then filled with soil as the termites' live medium. In order to maintain the humidity, 20 ml water is added. After that, subterranean termites (*Coptotermes* sp.) which consist of worker termites, soldier termites, and queen termite is situated inside soil-field aquarium and left them for 2 weeks in the dark, closed place with little aeration.In order to determine the anti-termite attack level, this following formula is proposed:

$$\text{Weight loss } (\%)\,(\text{P}) = \frac{\text{W1} - \text{W2}}{\text{W2}} \times 100\,\%$$

Notes P = weight loss (%); W1 = dry wood weight before the baiting (g); W2 = dry wood weight after the baiting (g).

Termite mortality is one of the indicators to determine the reactivity of termicide, particularly chitosan, borax, and imidacloprid contained in MDF (Hakim et al. 2011). The termite mortality is monitored daily. The following formula is employed to calculate the termite mortality:

$$\text{Mortality } (\%) = \frac{\text{N}_1}{\text{N}_2} \times 100\%$$

Notes N_1 = number of died termites after the baiting; N_2 = number of initial termites.

Water content

Water content test is conducted using wood moisture meter. The examination is conducted after the produced MDF is settled for 2 days and ready to be tested physically and mechanically.

Data analyses

Data analysis is conducted by Completely Randomized Design which is aimed to seek the influence of different seaweed waste's types on the MD products' physical, mechanical, and biological characteristics. If the seaweed type influences the physical, mechanical, and endurance of MDF, then an additional test, namely Duncan's Multiple Range Test (DMRT), shall be conducted in order to find out which seaweed type influences the physical, mechanical, and endurance of MDF the most (Kusriningrum 2008).

Results and discussions

Density

Density test is one of the physical characteristic tests which is aimed to compare between the object's mass to its volume or water equilibrium. Knowing the fibre board's density aims to determine its class: Low Density Fibreboard, Medium Density Fibreboard, or High Density Fibreboard. The density rate is influenced by cell's wall thickness, water rate, and adhesive process. The increasing density rate is also caused by adhesive solidification due to the tempering during MDF manufacture). In conclusion, MDF density in this research fulfills JIS A 5908 (2003) standard, approximately 0.4–0.8 g/cm^3. The average density of the particle board is presented in Table 1.

The highest density rate is recorded at P0 (100% sawdust), while the lowest is recorded at P_1 (100% *G. verrucosa*). It is caused by the total material weighs needed for MDF manufacture in order to achieve the designated density (0.4–0.8 g/cm^3), as well as having parallel length, width, and height across different treatments. Based on the result, it can be inferred that in order to fabricate a 20 × 20 × 2 cm^3 sized MDF, it is best to use 100% sawdust and most inadvisable to use 100% *G. verrucosa*.

Water content

The tested water content refers to the water rate of MDF which is given in the first treatment and conditioning to find out whether it has fulfilled the standard or not. According to JIS A 5905-2003, 5–13% water rate is considered as fulfilling the criteria as good quality MDF. Based on the test results, the average water rate from each MDF sample is obtained as in Table 1.

The water rate tests' results in Table 2 present that every treatment fulfills the standards to fabricate MDF. It is because the main materials, such as sawdust and seaweeds,

Table 1 Water content and physical properties of MDF (*Medium Density Fibreboard*)

Treatment	Average density (g/cm^3)	Average water content (%)	Average water absorbability (%)	Average thickness swelling (%)	MOE average (g/cm^2)	Average MOR (kg/cm^2)	Average Internal bond (kg/cm^2)	Average Internal bond (kg/cm^2)	Average screw holding rate (kg)
P0	0.7167	5.2667	16.0000	9.2000	13.888.8913	320.1800	2.5483	2.5483	40.1867
P1	0.6267	8.3000	26.3000	14.2333	13.889.9233	311.2000	2.5133	2.5133	40.2007
P2	0.5387	6.0091	23.5543	11.2338	13.784.3593	315.7885	2.5090	2.5090	40.1890
P3	0.6633	6.9000	20.2200	11.9333	13.958.1782	323.6789	2.5501	2.5501	40.2012
P4	0.5707	5.8007	19.5876	10.9667	13.689.1800	318.1273	2.5184	2.5184	40.1997
P5	0.6900	6.1333	16.6000	10.1667	13.724.8000	318.8143	2.5219	2.5219	40.2009
P6	0.6103	5.5000	16.4872	9.6735	13.116.7233	313.5443	2.5561	2.5561	40.1993
P7	0.6433	7.5667	22.9333	13.1667	13.668.2800	313.6709	2.5233	2.5233	40.2005
P8	0.5400	5.2777	22.0338	11.0887	13.613.0521	313.4917	2.5010	2.5010	40.2011

P0 100% sawdust; *P1* 100% *Kappaphycus alvarezii*; *P2* 100% *Gracilaria verrucosa*; *P3* 50% sawdust and 50% *Kappaphycus alvarezii*; *P4* 50% sawdust and 50% *Gracilaria verrucosa*; *P5* 75% sawdust and 25% *Kappaphycus alvarezii*; *P6* 75% sawdust and 25% *Gracilaria verrucosa*; *P7* 25% sawdust and 75% *Kappaphycus alvarezii*; *P8* 25% sawdust and 75% *Gracilaria verrucosa*

Table 2 Panelist Test Results

Scoring criteria	Repetition	Treatment			
		A (0%)	B (6%)	C (9%)	D (12%)
Visual appearance	i	2	3	3	2
	ii	2	3	3	2
	iii	2	2	2	2
	iv	2	2	2	2
	v	2	2	2	2
Hardness level	i	2	3	3	2
	ii	2	2	3	2
	iii	2	2	3	2
	iv	2	2	2	2
	v	2	2	2	2
Total		20	23	25	20

A MDF manufacture without adhesive; *B* MDF manufacture with 6% adhesive addition; *C* MDF manufacture with 9% adhesive addition; *D* MDF manufacture with 12% adhesive addition; score 1: not suitable; score 2: less suitable; score 3: suitable; score 4: very suitable

are sufficiently dry with low water rate after going through sun-drying process and oven-drying process.

The highest water rate is recorded at P1 treatment (100% *K. alvarezii*), because this particular seaweed contains the most water than the other materials. While P0 is recorded the lowest water rate, because the sawdust from *Acacia mangium* contains low water rate.

Absorbability

The tested absorbability is MDF water absorbability. It is conducted by soaking the board in the water for 24 h to obtain the additional weight of MDF board and its absorbability percentage against water. Based on the treatment results, average water probability is obtained and presented in Table 1.

High level of water absorbability is marked by the highest additional weight achieved after soaking the MDF. Water absorbability of MDF is not required under JIS A 5905-2003, however, it is necessary to be done in order to measure MDF quality, as it is associated with MDF's endurance and strength.

From the test result, the highest water absorbability rate is recorded at P1 treatment (100% *K. alvarezii*); while the lowest one is the P0 (100% sawdust). It is related to the completed MDF's density; at P0, it is recorded the highest density and it caused the lowest absorbability. It happens reversedly for P1 treatment.

Thickness swelling

Thickness swelling is conducted by measuring additional length of MDF which has been soaked in the water for 24 h. The test results of thickness swelling test are presented in Table 1.

Under the JIS A 5905-2003 standardization, the acceptable standard for the thickness swelling of MDF is less than 17%. Based on the obtained results, P0 treatment has the lowest thickness swelling rate, while P1 treatment recorded the highest rate; however, both still fulfill JIS A 5905-2003 standard. The results for thickness swelling rate is proportionally associated to water absorbability.

Mechanical test

Mechanical characteristic is related to strength and ability to endure the external forces which are capable to re-shape MDF. Mechanical characteristics for MDF consist of Modulus of Elasticity (MOE), Modulus of Rupture (MOR), Internal Bond, and Edge Holding Screw (Hakim, et al. 2011).

Modulus of Elasticity (MOE)

Modulus of Elasticity tests the object's endurance against elasticity. The mechanical characteristics are determined by the gradient of load deflection line. Based on the test results, the following MOE's average rates are presented in Table 1.

Based on the results above, the highest MOE rate is recorded by P3 treatment (50% sawdust and 50% *K. alvarezii*) while the lowest one is P6 treatment. According to JIS A 5905-2003 standard, it is mentioned that the minimum standard of MOE is 25,500 g/cm^2; thus, all treatments have not fulfilled the standardized criteria for MDF's modulus elasticity. However, in JIS 15 is mentioned that MDF at the third quality has the minimum standard of 13,000 g/cm^2; thus, all treatments have fulfilled the standardized MDF criteria for the third quality according to JIS 15.

Modulus of Rupture (MOR)

Modulus of Rupture (MOR) is the maximum strength of MDF board to endure other objects. Based on the test results, the average MOR can be seen in Table 1.

According to JIS A 5905-2003 standard, it is mentioned that MOE minimum standardized rate is 306 kg/cm$^{2:}$ thus, based on the table above, it can be concluded that all treatments fulfill the minimum standard. The highest rate is recorded by P3 treatment (50% sawdust and 50% *K. alvarezii*). It might be caused by the bond formation between two suitable and integrated materials; moreover, if the materials have the strongest compositions among the other treatments, so does the void between the formed bond which leads to the highest MOR rate.

The low rates of MOR for other treatments are caused by the lack of lignocellulose bonds among the materials; thus, when it is manufactured as a board, the fibre is not bonded tightly to each other. In addition, it is also caused by the defective bonding process on the board surface. If the manufacture of MDF and sludge board is compared, MDF has higher mechanical characteristics in which MOR recorded between 180 and 254 kg/cm^2.

Internal Bond

Internal Bond is one of the mechanical characteristics from the structural materials which indicate the bond rate between the adhesive material and MDF. Internal bond's test results are presented in the following Table 1.

Based on the table above, it is presented that all MDF samples do not fulfill JIS A 5905-2003 standard where the minimum standard of internal bond is 5.1 kg/cm^2. The low internal bond rate is influenced by the isocyanate bonding process with the fibre. The mixing process between adhesive and the materials (according to each treatment) is conducted by manual stirring (with hands); thus, there is a possibility of uneven adhesive spread to the fibre and this may cause poor adhesive strength of the MDF (Hakim et al. 2011).

Edge screw holding

Edge screw holding rate is the MDF strength to hold the planted screws on its surface. Based on the tests, these average edge screw holding rates are presented in the following Table 1.

JIS A 5905-2003′s minimum standard is 50.98 kg. Compared to the edge holding screw's result, the whole MDF samples do not fulfill the established standards. However, the result is in line with MOE, MOR, and internal bond tests in which MDF's strength is low due to the manual stirring during the mixing of the adhesive with the materials (according to its treatment). As a result, the strength to hold the connected screw to the MDF is low, because the bond among the fibre is not tied strongly. MDF still possess the same weakness as the other board types, namely the lack screw holding strength at the thick side, ineffective adhesive on the survey, and inability to hold the screw as strong as the solid wood (Hakim et al. 2011).

The next test for Medium Density Fibreboard (MDF) is conducted for P3 treatment with 50% sawdust and 50% *K. alvarezii* due to its benefits compared to other treatments during the physical and mechanical characteristics. The analysis on bonding ability on some treatments with different concentration (A treatment: MDF manufacture without any adhesive; B treatment: MDF manufacture with additional 6% adhesive; C treatment: MDF manufacture with additional 9% adhesive; D treatment: MDF manufacture with additional 12% adhesive) is focused to test MDF bioproduct which is resulted by physical test (density, water rate, absorbability, and thickness swelling) and mechanical test (MOE, MOR, Internal Bond, and Edge Screw Holding). The results are to be compared with Japanese Industrial Standard (JIS). The best treatment is determined by the number of parameters which nearly fulfilled the MDF criteria set by JIS.

The MDF's density test results on each treatment: A is recorded at 0% and 0.59 g/cm^3; B at 6% and 0.53 g/cm^3; C at 9% and 0.58 g/cm^3; and D at 12% and 0.65 g/cm^3. ANOVA analyses' results show that the inceasing adhesive concentration is not significantly different from the density rate ($p < 0.01$). The MDF density graphic at P3 treatment, which contains 50% sawdust and 50% *K. alvarezii* with the different addition of adhesive concentration, is shown by Fig. 1.

The test results of MDF moisture content of P3 treatment with 50% sawdust and 50% *K. alvarezii* along with the addition of different concentrations of adhesive on each treatment, namely A (0%), B (6%), C (9%) and D (12%) are 32.31, 15.31, 11.08 and 13.60%, respectively. The results of variance analysis showed an added adhesive concentration which is not significantly different ($p < 0.01$) from the value of the water content. The graph of MDF moisture content with the addition of different concentrations of adhesive can be seen in Fig. 2.

The test results of MDF absorption of P3 treatment with 50% sawdust and 50% *K. alvarezii* along with the addition of different concentrations of adhesive on each treatment, namely A (0%), B (6%), C (9%) and D (12%) are 11.35, 26.67, 88.11, and 70.87%, respectively. The results of variance analysis showed an added adhesive concentration which is significantly different ($p < 0.01$) from the value of the absorption. The graph of MDF absorption with the addition of different concentrations of adhesive can be seen in Fig. 3.

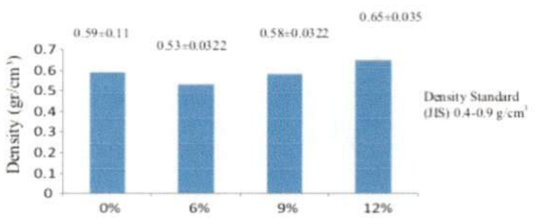

Fig. 1 The graph of MDF density with the addition of different adhesive concentration

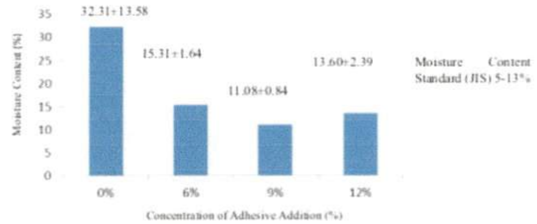

Fig. 2 The graph of MDF density with the addition of different adhesive concentration

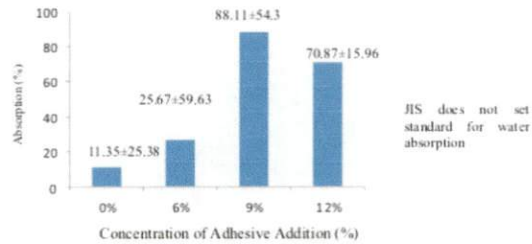

Fig. 3 The graph of MDF absorption with the addition of different adhesive concentration

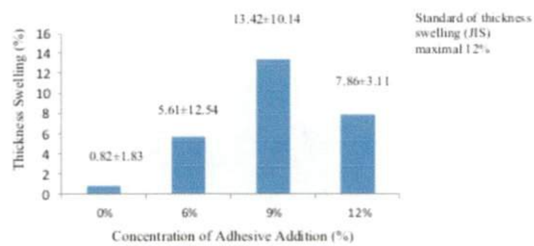

Fig. 4 The graph of MDF thickness swelling with the addition of different adhesive concentration

The test results of MDF thickness swelling of P3 treatment with 50% sawdust and 50% *K. alvarezii* along with the addition of different concentrations of adhesive on each treatment, namely A (0%), B (6%), C (9%) and D (12%) are 0.82, 5.61, 13.42, and 7.86%, respectively. The results of variance analysis showed an added adhesive concentration which is significantly different ($p < 0.01$) from the value of the thickness swelling. The graph of MDF thickness swelling with the addition of different concentrations of adhesive can be seen in Fig. 4.

The Modulus of Elasticity test results of MDF on each treatment A (0%), B (6%), C (9%) and D (12%) are 0.47×10^4, 0.54×10^4, 1.0×10^4 and 1.68×10^4 kgf/cm^2, respectively. The results of variance analysis showed an added adhesive concentration which is significantly different ($p < 0.01$) from the value of the Modulus of

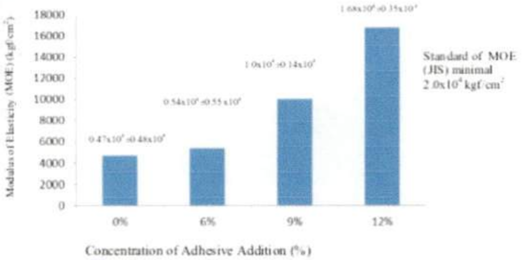

Fig. 5 The graph of MDF modulus of elasticity with the addition of different adhesive concentration

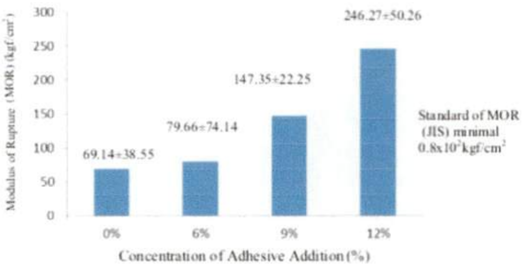

Fig. 6 The graph of MDF modulus of rupture with the addition of different adhesive concentration

Elasticity. The graph of MDF Modulus of Elasticity with the addition of different concentrations of adhesive can be seen in Fig. 5.

The Modulus of Rupture test results of MDF on each treatment A (0%), B (6%), C (9%) and D (12%) are 69.14, 79.66, 147, 35 and 246.27 kgf/cm^2, respectively. The results of variance analysis showed an added adhesive concentration which is significantly different ($p < 0.01$) from the value of the Modulus of Rupture. The graph of MDF Modulus of Rupture with the addition of different concentrations of adhesive can be seen in Fig. 6.

The screw holding power test results of MDF on each treatment A (0%), B (6%), C (9%) and D (12%) are 11.42, 13.17, 24.36, and 34.72 kgf, respectively. The results of variance analysis showed an added adhesive concentration which is not significantly different ($p < 0.01$) from the value of the screw holding power. The graph of MDF screw holding power with the addition of different concentrations of adhesive can be seen in Fig. 7.

The determination of MDF appearance and rigidity/hardness ratings is obtained by scoring conducted by panelists who were given the score of each MDF treatment. The value of DF appearance and rigidity/hardness approaching the set of criteria will be given the highest score, and the value which is further away from the criteria will be given the lowest score. Table 2 showed is a score

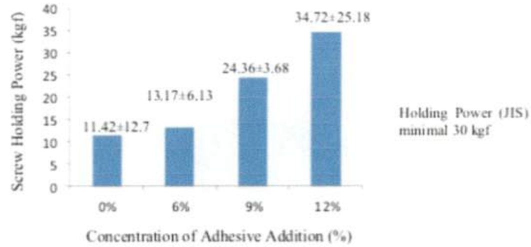

Fig. 7 The graph of MDF screw holding power with the addition of different adhesive concentration

table of MDF appearance and hardness that use panelists test.

The assessment criteria which were important in the selection of the best adhesive concentration is density, moisture content, absorption, thickness swelling, Modulus of Elasticity, Modulus of Rupture, the internal bond, and screw holding power. The determination of the best treatment is obtained by means of scoring by the panelists who were then given the rankings of each MDF treatment. The values of density, moisture content, absorption, thickness swelling, Modulus of Elasticity, Modulus of Rupture, internal bond, and screw holding power which approach the Japanese Industrial Standards (JIS) criteria will be given the highest score, and those which are far from the Japanese Industrial Standards (JIS) criteria will be given the lowest score. The score of each treatment is summed and given rankings to get the best treatment. Table 3 shows a comparison table of MDF parameter values that had been given treatment according to JIS.

The comparison results of the MDF parameter values with the Japanese Industrial Standards (JIS) is used for the final score assessment for each treatment of adhesive concentration addition. The adhesive concentration addition as much as 12% (treatment D) has the best criteria of density, thickness swelling, Modulus of Elasticity, Modulus of Rupture and screw holding power, compared to other treatments. Meanwhile, the best value of the water content is found in treatment C (concentration of adhesive 9%), and the best absorbency is found in treatment A (adhesive concentration 0%) (Table 4).

The research continued to test the activities of anti-termites *Coptotermes sp.* toward the MDF, which involved a number of termiticides (chitosan, borax, and imidacloprid). In this study, the weight loss of MDF made from seaweed *K. alvarezii* was calculated at the beginning of the test and at the end of the test. The results of variance analysis (ANOVA) conducted from the start of the test until the end of the test indicated that any anti-termite treatment administration gives a significantly different effect on weight loss to MDF made from seaweed *K. alvarezii* ($p < 0.05$).

Table 3 A comparison of MDF parameter values with JIS

Parameter	Treatment				JIS
	A (0%)	B (6%)	C (9%)	D (12%)	
Density (g/cm^3)	0.59	0.53	0.58	0.65	0.4–0.9
Moisture Content (%)	32.31	15.31	11.08	13.60	5–13
Water absorption (%)	11.35	26.67	88.11	70.87	–
Thickness swelling (%)	4.08	28.03	13.42	7.86	Maks 12
MOR (kgf/cm^2)	69.14	79.66	147.35	246.27	Min 0.8×10^2
MOE (kgf/cm^2)	0.47×10^4	0.54×10^4	1.0×10^4	1.68×10^4	Min 2.0×10^4
Screw holding power (kgf)	11.42	13.17	24.36	34.72	Min 30

A MDF manufacture without adhesive; *B* MDF manufacture with 6% adhesive addition; *C* MDF manufacture with 9% adhesive addition; *D* MDF manufacture with 12% adhesive addition

Table 4 Scoring results and MDF ranking by panelists

Parameter	Adhesive concentration			
	A (0%)	B (6%)	C (9%)	D (12%)
Density (g/cm^3)	3	1	2	4
Moisture Content (%)	1	2	4	3
Water absorption (%)	4	3	1	2
Thickness swelling (%)	2	1	3	4
MOR (kgf/cm^2)	1	2	3	4
MOE (kgf/cm^2)	1	2	3	4
Screw holding power (kgf)	1	2	3	4
Appearance	1	4	3	2
Hardness level	1	2	4	3
Total Score	15	19	26	30
Ranking	4	3	2	1

In the control or the treatment without any termite, the average value of MDF weight loss percentage is 8.164%. In MDF treatment with the addition of chitosan, the average value of weight loss percentage is 4.338%. This value is not significantly different from the treatment of MDF with the addition of borax, in which the value of the average weight loss percentage is 4.118%. The average value of the percentage in the treatment of MDF with the addition of imidacloprid is 0.422%.

This study also tested the termite mortality in each treatment which was calculated for two weeks. At the end of the study, data were obtained which showed termite mortality in each treatment as shown in Table 5.

In the control or the treatment without any termite on MDF made from seaweed *K. alvarezii*, the mortality value of subterranean termites *Coptotermes* sp. amounted to 77.6%. MDF treatment with the addition of chitosan showed a mortality value of 97.6%; the treatment of MDF with the addition of borax got the value of mortality of 98.8%, and MDF treatment with the addition of imidacloprid showed the value amounted to 100%. Anti-termites added in MDF made from seaweed *K. alvarezii* have the toxic power to *Coptotermes* sp. Time of death of the subterranean termites *Coptotermes* sp. on each treatment was different. The fastest time of mortality was found in MDF containing imidacloprid which is about 4 days. The results of variance analysis (ANOVA) performed during the test indicates that any provision of anti-termite treatment gives a significantly different effect on the mortality of termites ($p < 0.05$).

Table 5 The percentage of mortality data of termite *Coptotermes* sp. during the MDF testing

Anti termite	Mortality (%) ± SD
Control	77.6^b ± 7.26
Chitosan	97.6^a ± 5.36
Borax	98.8^a ± 2.68
Imidacloprid	100^a ± 0.00

Different superscript letters indicate significant difference ($p < 0.05$)

Measuring the quality of soil, such as moisture, pH and temperature, was performed at the beginning and end of the study. The measurement of the temperature used a thermometer, while the humidity and pH measurement used a measuring instrument ground ETP-303 3 in 1. At the beginning of the soil measurement, a temperature of 29 °C was obtained at each test medium. A different temperature, which is 30 °C, was only obtained in the control treatment. Humidity measurement data in the control treatment and chitosan obtained mixed results, namely 70–80%, while the treatment of borax and imidacloprid showed the same result which is 70%. The measurement of pH at the beginning obtained the same results in each treatment, which is 7.

The measurement at end of the study obtained varying temperature degrees but it still shows the normal range for subterranean termites *Coptotermes* sp. growth. The anti-termite treatment and the treatment without added chitosan

Table 6 Parameter range of soil quality

Parameter	Range
Soil moisture (%)	70–90
Temperature (°C)	29–31
pH	6–7

obtained temperature ranging from 29 °C to 30 °C, while the treatment of added borax and that of added imidacloprid obtained temperature ranging from 29 to 31 °C. The measurements on moisture obtained in each treatment ranged from 70 to 90%. The soil pH measurements obtained in each treatment ranged from 6 to 7 (Table 6).

Discussion

MDF density is an important parameter influencing the formation of MDF. It can be seen that the density between treatments A, B, C and D is not the same. Each treatment produces different density, but after being tested using analysis of variance it is known that the addition of adhesive concentration was not significantly different to the MDF density produced. This is due to the fact that the MDF board is made of *K. alvarezii* seaweed and sawdust mixture with the same comparison and with the same adhesive ingredients, so that it was not significantly different from the MDF density produced. According to Kelly (1977), the amount of density of particle board is influenced by the density of the materials, the content of adhesives, and the additives used. According to the Japanese Industrial Standard (JIS) (2003) MDF boards that can be used in the market have a density of 0.4–0.9 g/cm^3. Based on the JIS, *K. alvarezii*-based MDF in the study meet the standard to be categorized as MDF board because the resulting density ranges from 0.5 to 0.6 g/cm^3.

The water content is the ratio between the mass of water in timber or composite board with a mass of wood or composite boards in kiln-dry conditions and expressed in percentage (Hakim et al. 2013). From the analysis of variance it is known that the addition of adhesive concentration was not significantly different from the value of the moisture content of the MDF. Each treatment produced different moisture content levels. The highest moisture content value is obtained in treatment A with 0% adhesive or without any adhesive. This is due to the absence of adhesive that holds MDF particle component parts to each other, so that the surface of the particle board MDF is getting bigger and absorbing more moisture from the environment.

Based on the Japanese Industrial Standards (JIS), the moisture content determined for MDF production is 5–13%. The water content in treatment A with 0% adhesive or without the use of adhesive or adhesive did not meet the standards because the moisture content value obtained exceeds the standard that is 32.31%. Treatment C (9% adhesive) is the only one that meets the standards of the water content in accordance with JIS. Water absorption is the board's ability to absorb water after being soaked for 24 h. From the analysis of variance it is known that the addition of adhesive concentration is highly significant to the value of water absorption. Each treatment produces different absorption values. In treatment C (9% adhesive) the addition of adhesive concentration was not significantly different from treatment D (12% adhesive) but significantly different from treatment A and B. The highest absorption value is found in the treatment C with the addition of adhesive concentration of 9%, which amounted to 88.11%, while the lowest value of absorption is found in treatment A (without using adhesive or 0% adhesive) with a value of 11.35%. This can occur because extractive substances contained in seaweed are more soluble in water so that the bonding that occurs between the particles is more compact and more resistant to water; besides, it is assumed that there is less time of pressing. This is in accordance with Puspita's argument (2008) that longer time of pressing will produce a more compact and condensed bond between particles so that there is less entry space of water into the boards. In this study, the time of pressing used is 25 min. The Japanese Industrial Standard (JIS) (2003) does not set standards for water absorption. MDF water absorption value in this study ranges from 11.35 to 88.11%. Water absorption test is done to determine the water resistance of the board used for exterior use or the use that is often directly related to the effects of weather (rain water and moisture) (Puspita 2008).

Thickness swelling is dimensional changes of wood thickness due to changes in the moisture content of the wood. From the analysis of variance it is known that the addition of different concentrations of adhesive is highly significant to MDF thickness swelling. Each treatment produces different value of thickness swelling. The highest value of thickness swelling is found in treatment C with the addition of adhesive concentration of 9% amounting to 13.42%, while the lowest value of thickness swelling is found in treatment A (without using adhesive) with a value of 0.82%. In MDF with treatment C (adhesive 9%), the thickness swelling exceeds the standard set by Japanese Industrial Standard (JIS). The maximum value of thickness swelling according to JIS standard is 12%, while in treatment C (adhesive 9%) the value is 13.42%. According to Setyawati et al. (2006), the exceeding value happens because the composite board contained empty cavities that allow water to enter at the time of immersion.

Based on JIS standard related to the value of thickness swelling categorized as good MDF, the criteria include treatment A (adhesive 0%), B (adhesive 6%) and D (adhesive 12%) with values ranging from 0.82 to 7.86%, which do not exceed the maximum limit of thickness swelling. This is in accordance with the research conducted by Lubis et al. (2011) that the high value of thickness swelling of a composite board means the dimensional stability of the product is so low that the product cannot be used for exterior purposes and its mechanical properties will decrease within a short time.

Modulus of Elasticity (MOE) is the board's mechanical properties which show the ability to withstand loads up to the limit the proportion often called as Modulus of Elasticity. MDF Modulus of Elasticity is affected by the addition of an adhesive concentration, in which the highest value of Modulus of Elasticity is found in treatment D (adhesive 12%), which is 1.68×10^4 kgf/cm^2, while the lowest value is found in treatment of A (adhesive 0%), i.e. 0.47×10^4 kgf/cm^2. Results of analysis of variance showed that the addition of adhesive concentration is highly significant to the Modulus of Elasticity.

The MDF's Modulus of Elasticity value increased in line with the increasing concentration of adhesive. This is due to the increasing concentration of the adhesive used, so that the adhesion between particles becomes denser and the Modulus of Elasticity becomes higher. In this study, however, the value approximate to the criteria set by JIS is found in treatment D (adhesive 12%) which is 1.68×10^4 kgf/cm^2. Thus the Modulus of Elasticity of *K. alvarezii*-based MDF does not meet the standards to be categorized as MDF, since the Modulus of Elasticity value generated only ranged from 0.47×10^4 kgf/cm^2 to 1.68×10^4 kgf/cm^2.

Modulus of Rupture or MOR test is used to determine the level of board strength in weight-bearing until the board breaks. From the analysis of variance it is known that the addition of adhesive concentration is highly significant to the Modulus of Rupture value. Each treatment produces different value of Modulus of Rupture. The Modulus of Rupture value of MDF increased in line with the increasing concentration of adhesive. The highest value of Modulus of Rupture is found in treatment D (adhesive 12%), which is 246.27 kgf/cm^2, while the lowest value is found in treatment of A (adhesive 0%), which is 69.14 kgf/cm^2. Based on JIS standard on the Modulus of Rupture value categorized as good MDF, the criteria include treatment C and D with a value ranging from 147.35 to 246.27 kgf/cm^2, which is above the minimum set by JIS, i.e. 80 kgf/cm^2.

Screw holding power is the ability of a composite product to withstand the load screw provided on the composite board. It is seen from the research that the screw holding power of MDF is influenced by the addition of an adhesive concentration. The highest value of screw holding power value is found in treatment D (adhesive 12%), i.e. 34.72 kgf while the lowest value is found in treatment of A (adhesive 0%), i.e. 11.42 kgf. The results of variance analysis showed that the addition of adhesive concentration was not significantly different to the MDF screw holding power. MDF screw holding power value increases in line with the increasing concentration of adhesive. Based on JIS, the screw holding power of *K. alvarezii*-based MDF that meet the standards to be categorized as good MDF good is found in treatment D with a value of 34.72 kgf, while in treatment A, B and C the value of screw holding power is under JIS standards. This could be due to the occurrence in the manufacturing process of MDF resulting in the emergence of cavity so the screw holding power tends to decline.

Panelists test was conducted to determine the visual appearance and the hardness level of the MDF produced. This testing was done by matching the MDF treated in this study with the MDF sold in the market based on the assessment criteria set. This panelists test is objective meaning that the scoring depends on the scorer. In this research, the result of MDF products can be said to be good, and some tests has already meet the standards set by JIS. Based on these results, it can be said that *K. alvarezii* seaweed has good potential to be used as raw material for the manufacture of MDF.

The weight loss test on *K. alvarezii*-based MDF was done in accordance to SNI 01-7207-2006, which is testing the durability of wood that do not provide food to the termites (no choice laboratory test), where there is no choice other than the test sample given to the termite. The observation on termite feeding activity is used to see the weight loss of the test sample fed to the subterranean termites (Sejati 2012). The MDF made from seaweed *K. alvarezii* without anti-termite fed to the termites underwent weight loss. The weight lost test result on the MDF without anti-termite shows the highest result, which is 8.164%. This MDF weight loss is due to the fact that the cellulose contained in the MDF is termite's favorite food. In general, termite feeding activity is influenced by the availability and preference level of termites to sources of food and the environment. Termites are wood eating insects or materials containing cellulose (Hakim et al. 2011). The MDF made from seaweed *K. alvarezii* added with chitosan or borax which was fed on termites also underwent weight loss, but the weight loss is not much compared to that of MDF made from seaweed *K. alvarezii* without anti-termite. The administration of chitosan can interfere with the termites eating pattern because cellulose is mixed with the active ingredient contained in the chitosan. The MDF added with chitosan has a lasting pace attack against termites. According to Tobing (2007), chitosan is non-toxic (slow action) and it works by interfering the performance of protozoa in the termites' digestive systems so that the termites find it hard to find food produced by the protozoa. The borax added to the MDF can also disrupt the eating pattern of termites because the cellulose is mixed with the active ingredient contained in borax. MDF added with borax can reduce the occurrence of weight loss due to termite damage. This is possible because boron has an active ingredient in the form of boric acid (boron compound) that affects the termite's digestion system. Febriana et al. (2012) state that preservatives containing boron compounds are toxic to termites *Coptotermes* sp. Holmgren.

MDF made from seaweed *K. alvarezii* supplemented with imidacloprid fed to the termites underwent a slight decrease from the initial weight. This means that the termite attack on the MDF is minimal or even zero. The active ingredient contained in imidacloprid added to the MDF can interfere with the termites' eating pattern. Termites' eating pattern was disrupted because it is depressed with food not preferred by termites, so that the termites did not eat the MDF added with imidacloprid. The imidacloprid added to the MDF can also disrupt the nervous system of the termites. Termites that eat the imidacloprid-added MDF will experience weakness because the nervous system is not functioning and then the termites will die slowly. The effective speed of imidacloprid in killing termites is higher (toxic) than that of other anti-termites. The moisture content in the MDF before and after the weight test should be measured. It should be done so that the weight loss on MDF in the test is only influenced by the activity and the level of eating preference of the termites. The moisture content of the MDF ranged from 10.05 to 12.10%. According to Japanese Industrial Standard (JIS) A 5908-2003, it is required that the moisture content in composite board be 5–13%.

Termite mortality is one indicator in determining the level of effectiveness of anti-termite material mixed into MDF made from seaweed *K. alvarezii* against termites. The percentage of termite mortality can be obtained from the calculation of termites died during the tests of MDF made from seaweed *K. alvarezii*. The test results showed that the MDF made from seaweed *K. alvarezii* mixed with anti-termites can kill termites effectively than the MDF made from seaweed *K. alvarezii* without anti-termites. The highest value of termite mortality is obtained in the treatment of MDF made from seaweed *K. alvarezii* mixed with imidacloprid, while the lowest value of termite mortality is found in the treatment of MDF made from seaweed *K. alvarezii* without being given anti-termite. The low mortality in MDF made from seaweed *K. alvarezii* without being given anti-termite is because *K. alvarezii* seaweed used as MDF material contains cellulose. According to Hakim et al. (2011) termites are wood-eating insects or materials containing cellulose.

Observations on MDF made from seaweed *K. alvarezii* mixed with the anti-termites, namely chitosan, borax and imidacloprid, showed high mortality during testing. Imidacloprid mixed with MDF made from seaweed *K. alvarezii* shows effective results, amounting to 100%. At the beginning of the test, the animals in the test experienced mass death. This is possible because the active ingredients are not preferred by termites. According to Cox (2001), imidacloprid contains an active ingredient called neonicotinoid or nicotinoid that works like natural nicotine (tobacco), which is interfering with the nervous system of the termites.

Soil quality such as moisture, pH and temperature are environmental factors that support the survival of test animals. This is explained by Iswanto (2005) that humidity and temperature are factors that influence the activity of termites. In the initial preparation, the soil used as test medium was taken on the habitat of termites found in nature so that it is suitable with the habitat of the test animals. The soil used as a medium of life was initially measured to give conformity and uniformity in the test animals' living habitat. Temperature is an important factor affecting the insect's life, both on the development and activity (Iswanto 2005). The temperature measured at the initial measurement was about 29–30 °C in all treatments. According to Nandika et al. (2003), the optimum temperature in termites' living habitat is 29–30 °C.

The termite's cruising activity is strongly influenced by humidity so that for the testing spraying with water was conducted on the test medium. This was necessary to keep the moisture in the test animals' living habitat. The humidity at the beginning of the measurement obtained humidity was around 70–80% in all treatments. According Nandika et al. (2003) the optimum development of humidity is in the range of 75–90%. Acidity (pH) of the soil also affects the activity of termites. The results of pH measurement in this study ranged from 6–7. According to Subekti et al. (2008), the type of soil suitable for termite habitat is land containing hummus and slightly sandy with acidity (pH) from 6 to 7. After testing the MDF made from seaweed *K. alvarezii* with various treatments, the measurements of the temperature and humidity were then conducted at the end of the test. This is done to determine that the mortality of termites used as test animals is due to the influence of anti-termite instead of the poor soil quality. In the last measurement in the study, it is shown that the mortality of termites is heavily influenced by the level of toxicity of the anti-termite contained in the MDF products.

A number of possible mechanisms of termite mortality caused by the active ingredient contained in the anti-termite mixed into the MDF is as follows. The first possibility is the active ingredient found in anti-termite can be deadly to protozoan as the termite symbiont in decomposing cellulose in the digestive systems of termites. The death of protozoa will cause disruption on the activity of cellulase enzyme issued by protozoa, allowing the termites to die for not gaining the energy and food needed to survive. According to Rismayadi and Arinana (2009), the anti-termite mechanism is because the anti-termite has bioactive compounds that can kill microorganisms. The protozoa found in the digestive system of the termites secrete cellulase enzymes that allow the termites to decompose the wood so the termites can obtain energy for development and growth. The death of protozoa found in the stomach of termites deactivates the cellulase enzymes so that termites are not able to decompose the MDF, leading to death in termites (Prawira et al. 2012).

The second possibility is that the active ingredient of anti-termite damages the nervous system and causes the nervous system to not function and will eventually kill the termites. Arif et al. (2006) mentioned that the bioactive compounds contained in anti-termite have a very large role in improving the anti-termite properties in killing termites. The bioactive compounds can also damage the nervous system termites causing the dysfunctional nervous system which ultimately killing termites. Symptoms caused by the three anti-termites vary. Symptoms caused by the active ingredient of chitosan and borax added to the MDF lead to the termites' weak condition due to the disrupted eating patterns or poisoned digestive system, leading to the death of termites. There is discoloration on the abdomen of worker termites which is blackish and the warrior termites which are darker than reddish brown; the termite's body also becomes dry and crumbly. The changes as shown in the symptoms of such attacks are in accordance with Hutabarat et al. (2015), who stated that the dead termites undergo changes including body color and body shape. Body color changes from pale white into a blackish brown color and body shape indicates dryness. The other thing shown by the attack symptoms in the MDF added with imidacloprid is the visual observation of dead termites which get attached to the MDF. This is possible because the effects of bioactive compounds of imidacloprid can damage cell membranes, inactivating the cell enzymes and damaging cell proteins. Bioactive compounds can damage the nervous system of the termites causing the nervous system not functioning and ultimately killing termite (Azis 2013).

Based on the results of these studies, the abundant *K. alvarezii* in Indonesia, both cultivated and naturally growing, is potential to be used as a diversified media of qualified bioproduct manufacturing and is expected to reduce the damage to the forest ecosystem as a result of the use of wood as popular MDF materials.

Conclusion

The test results of physical properties of MDF samples produced entirely meet the standard of JIS A 5905-2003, while the mechanical test results that meet the standards of JIS A 5905-2003 are found in treatment P3 (Sawdust 50%, *K. alvarezii* 50%). the abundant *K. alvarezii* in Indonesia, both cultivated and naturally growing, is potential to be used as a diversified media of qualified bioproduct manufacturing and is expected to reduce the damage to the forest ecosystem as a result of the use of wood as popular MDF materials. The addition of adhesive with different concentrations in the manufacture of *K. alvarezii*-based MDF provides significant effect ($p < 0.01$) against water absorption, thickness swelling, Modulus of Elasticity and Modulus of Rupture, but gives insignificant effect ($p < 0.01$) to the density, moisture content and screw holding power of the MDF produced. The best treatment is found in D (adhesive addition of 12%) with a density value of 0.65 g/cm^3, 7.86% thickness swelling, Modulus of Elasticity 1,68 × 10^4 kgf/cm^2, Modulus of Rupture 246.27 kgf/cm^2, and screw holding power of 34, 72 kgf which generally meet the JIS, except water content and water absorption. The weight loss of Medium Density Fiberboard (MDF) made from seaweed *K. alvarezii* plus imidacloprid is 0.422%. The weight loss of MDF coupled with chitosan is 4.338%, and that of MDF coupled with borax is 4.118%, so in this study the addition of imidacloprid in MDF made from seaweed *Kappaphycus alvarezii* is the most effective in preventing termite attack.

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