Utilization of Water Hyacinth (*Eichhornia crassipes*) and Corncob (*Zea mays*) in Epoxy-based Biocomposite Board for Cool Box Thermal Insulation Material

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Abstract. Generally, the cool box is produced using styrofoam as the main thermal insulation material. However, the use of styrofoam potentially cause pollution to the environment at the end of its useful life because it cannot decompose naturally. The effort to overcome this problem is by producing thermal insulation materials from natural sources such as water hyacinth and corncob. The purpose of this study was to determine the characteristics of biocomposite board made from combination of water hyacinth powder and corncob ash based on physical, mechanical, and thermal conductivity analysis. Biocomposite boards were produced by introducing combination of water hyacinth powder and corncob ash (5, 10, 15%wt) into epoxy resin. The ratio of water hyacinth powder and corncob ash were 100:0 (P0), 95:5 (P1), 90:10 (P2), 85:15 (P3). The biocomposite boards were also made from water hyacinth powder and corncob powder, which ratio of 15:85 (P4) and 0:100 (P5). The results of this research revealed that type P5 board had the lowest density value (0.927 g/cm³) and the lowest water absorption value (1.53%). The P2 type board shows the highest bending strength (8.6 N/mm²) which met the requirements of JIS A 5908 for particleboards type 8. The highest value of compressive strength was observed at P5 type board which was 2.94 ± 0.53 N/mm². The lowest thermal conductivity values were observed at P2 type boards (0.305 W/mK). It can be concluded that, P2 type board had the best thermal insulator properties among other boards in this study. The thermal insulation effectiveness assessment of biocomposite board for cool box application was conducted using P2 and P5 type boards. The assessment results demonstrated that the styrofoam cool box and commercial cool box performance for maintaining temperature were superior compared to biocomposite cool box. Therefore, it is necessary to re-examine the biocomposite cool box, especially in terms of panel assembling and the shape of the lid, to produce biocomposite cool box with thermal insulator properties comparable to the commercial cool box.
1. Introduction

Indonesia is a maritime country which its ocean area is broader than land area. According to the Ministry of Marine Affairs and Fisheries, the total area of Indonesia is 7.81 million km$^2$ consisting of 2.01 million km$^2$ of land, 3.25 million km$^2$ of ocean, and 2.55 million km$^2$ of the Exclusive Economic Zone (EEZ) [1]. From such a vast ocean, fish is the main marine product that is a source of income for fishermen. The growth of the Indonesian fishery sector provides a significant contribution to the country's foreign exchange. However, the increase in marine fish catches, in fact, is not necessarily followed by an increase in the availability of fresh fish both for direct consumption and as raw materials for the fish processing industry. Most of the fishermen still use the technique of catching and handling fresh fish with simple equipment, thus affecting the quality of the fresh fish produced.

One of the factors that determine the selling value of fish is the level of freshness [2]. Handling of fresh fish should start immediately after the fish is harvested with low temperature treatment and pay attention to sanitation and hygiene. The main problem on handling fish is the rapid decline on the quality of a fish due to improper handling. Fresh fish need to be kept in a temporary container called a cool box. So far, traditional fishermen often use a styrofoam cool box to maintain temperature. However, the styrofoam boxes tends to break easily, cannot withstand heavy loads so that they are easily damaged [3]. The use of styrofoam boxes also has the potential to pollute the environment at the end of its useful life, because it cannot be decomposed naturally, moreover the basic material for its manufacture comes from petroleum whose supplies are running low. In addition to styrofoam boxes, there are cooler boxes made from vacuum insulation panels and polyurethane foam, with better quality, both in terms of strength, as well as their ability to maintain temperature compared to styrofoam boxes. However, the price of polyurethane foam cool boxes is quite expensive and is not affordable for fishermen.

Composite with the addition of natural fibres is one of the alternative materials that can be developed for the manufacture of thermal insulation cool box. One of the potential natural fibres as reinforcement in composites is water hyacinth fibre. Water hyacinth is a plant that has a high growth rate and easily spreads through waterways, so it is considered a weed because it can damage the aquatic environment. In Indonesia, the water hyacinth population is abundantly but its utilization has not been optimized. Water hyacinth contains 25% cellulose, 33% hemicellulose and 10% lignin [4]. Water hyacinth fibre in the composite can help maintain temperature because one of the properties of natural fibres is as a heat insulator [5]. Therefore, water hyacinth fibre has the potential to be used in epoxy-based biocomposite boards that can function as a thermal insulator in cool box production.

Utilization of water hyacinth fibre can be combined with raw materials containing silica so that it can function as a better heat insulator. One of the natural ingredients that contain a lot of silica is corncob, which is a waste that has not been utilized optimally. Water hyacinth fibre and corncob ash are potential raw materials for the manufacture of thermal insulation cool box. The purpose of this study was to analyze the physical, mechanical, thermal conductivity of epoxy-based biocomposites with water hyacinth powder and corncob ash as a filler.

2. Materials and Method

Water hyacinth was obtained from the pond around SMAN 3 Denpasar. Corncobs are obtained from household kitchen waste. The epoxy resin (Epichlorohydrin in Bisphenol – A) and hardener (Triethylenetetramine), produced by PT Avia Avian (Avian Brands) were used as adhesives for biocomposite boards production. Sodium hydroxide (NaOH) at technical grade was used for chemical treatment on water hyacinth fibres to eliminate dirt and lignin.
2.1. Raw material preparation
The clean water hyacinth stems were air-dried, before the fibres were separated. The water hyacinth fibres were soaked with 5% NaOH solution (w/w) for 2 h to remove the elements contained in the fibres, such as oil, dirt, colour elements, and others [6]. The soaked fibre, then rinsed using clean water, dried, grinded and then sieved with a 20-mesh wire screen to obtain smaller and uniform water hyacinth powder.

The fresh corncobs were cut into smaller pieces and sun-dried for about 1-2 days until the moisture content was about 11%. The dried corncob was then grinded and screened to obtain corncob powder. In addition, corncob ash was obtained by combusting corncobs using a muffle furnace at a temperature of 650 °C for 4 hours.

2.2. Raw material characterization
The crystallinity degree of corncob powder and corncob ash was observed using an X Ray Diffractometer (XRD) Rikagru SmartLab with an X-ray intensity of 40kV, 30mA, scan rate 5°/min with the 2θ angle range of 2°-60°. The morphology of water hyacinth fibres and corncob were observed by Keyence Digital Microscope with magnification of 50x and 200x.

2.3. Biocomposite production
The manufacture of biocomposites have been carried out based on the formula in Table 1. Total filler weight in the composite board was 11% (w/w). Firstly, epoxy resin and epoxy hardener were mixed with ratio 1:1 (v/v). After the adhesives were well-mixed, water hyacinth powder or corncob ash or corncob powder by amount according to the formulation in Table 1, were added into the adhesive, and mixing process was continued until completely blended. Subsequently, the mixture was poured into the mould (20 x 20 x 1 cm), immediately and stored for 12 hours until solidified. For each formula, 2 boards are produced. The boards were then cut according to the size of the test sample for analysis of moisture content (5 x 5 cm), analysis of water absorption and thickness swelling (5 x 5 cm), analysis of bending strength (5 x 20 cm), analysis of compressive strength (1 x 5 cm) and thermal conductivity analysis (2 cm in diameter, 1 cm in height).

| Sample Code | Water hyacinth powder (g) | Corncob ash (g) | Corncob powder (g) | Epoxy resin (ml) | Epoxy hardener (ml) |
|-------------|---------------------------|----------------|-------------------|-----------------|-------------------|
| P0          | 55                        | 0              | 0                 | 250             | 250               |
| P1          | 52.25                     | 2.75           | 0                 | 250             | 250               |
| P2          | 49.5                      | 5.5            | 0                 | 250             | 250               |
| P3          | 46.75                     | 8.25           | 0                 | 250             | 250               |
| P4          | 46.75                     | 0              | 8.25              | 250             | 250               |
| P5          | 0                         | 0              | 55                | 250             | 250               |

2.4. Physical properties of the biocomposite boards
The board density was calculated by comparing its weight and volume. Changes in thickness and changes in weight of the board after immersion for 24 hours were measured to obtain data on the board thickness swelling and water absorption. The physical properties testing was continued by observing the resistance of the board after repeated soaking and drying treatments (cyclic treatment). Changes in board thickness and weight were calculated after several treatments which were: (a) soaking for 24 h, (b) drying in an oven at
105°C for 4 h, (c) soaking in hot water at 70°C for 4 h, (d) drying in an oven at 105°C for 4 h, (e) boiling at 90-95°C for 4 h, (f) drying in an oven at 105°C for 4 h.

2.5. Mechanical properties of the biocomposite boards
The mechanical properties of the board were analyzed by bending strength test and compressive test, using a universal testing machine (UTM) Shimadzu Autograph 50kN. Bending strength testing was conducting by 3 points test bending, with a load speed of 10 mm/min and support distance of 15 cm, based on standard method of JIS A5908. Compressive testing was conducting based on ASTM D 695-96 with a load speed of 5 mm/min.

2.6. Thermal conductivity analysis of the biocomposite boards
The thermal conductivity measuring refers to the ASTM E 1225-13 standard, using thermal conductivity analyzer, C-Therm / TCi at Physics Research Centre, Indonesian Institute of Sciences, Serpong, West Java, Indonesia.

2.7. Thermal insulation effectivity analysis of the cool box
The thermal insulation effectiveness test aims to compare the frost resistance in the cool box made from biocomposite boards (biocomposite cool box), styrofoam box and commercial cooler box. The steps for conducting a thermal insulation effectiveness test were as follows: (1) Put 1 Kg ice block into the biocomposite cool box as well as into styrofoam box and commercial cooler box, (2) Prepare a digital thermometer probe in each box, make sure the thermometer was installed in a hanging position and was not in direct contact with the ice block or water from the melting ice. Thus, the thermometer reads the room temperature in the cool box, (3) A thermometer was also installed in the room where the experiment was carried out to determine the room temperature, (4) Record the temperature every 1 hour. This analysis was carried out until the ice in the cool box had melted.

3. Result and Discussions
3.1. Raw material characterization
The cross section of water hyacinth fibre and corncob was analyzed using digital microscope (Figure 1a and Figure 1b). The water hyacinth fibres were observed to be in a tight-knit group of fibre bundles, and there were large lumens representing air holes. This is the main reason the plant is lightweight and able to float on the surface of the water. Corncob is the central core of maize (Zea mays sp.), and the part on which the maize kernels grow. The innermost part colour of the corncob is white and has a consistency similar with foam plastic. Corncob is a lignocellulosic material composed of cellulose (38.8% ± 2.5%), hemicellulose (44.4% ± 5.2%) and lignin (11.9% ± 2.3%) [7].

![Figure 1](image-url) Cross section of (a) water hyacinth fibre (30x magnification), (b) water hyacinth fibre (200x magnification), and (c) corncob (50x magnification).
The XRD pattern shown by corncob powder was different from that of corncob ash (Figure 2). The XRD pattern of corncob powder shows the characteristics of a semi-crystalline material, while the XRD pattern of corncob ash shows the characteristics of a crystalline material. The diffraction peaks and the critical size of corncob powder and corncob ash are presented in Table 2 and Table 3.

Table 2. Diffraction peaks on XRD graph of corncob powder

| No. | 2-theta (°) | D (Å) | Height (cps) | FWHM (°) | Int. I (cps °) | Size (Å) |
|-----|-------------|-------|--------------|----------|---------------|----------|
| 1   | 16.490      | 5.370 | 4499         | 6.52     | 31234         | 12.90    |
| 2   | 21.756      | 4.082 | 12779        | 6.02     | 153683        | 14.04    |
| 3   | 34.820      | 2.574 | 1753         | 8.40     | 26718         | 10.30    |

Figure 2. Diffractogram of (a) corncob powder and (b) corncob ash.

Table 3. Diffraction peaks on XRD graph of corncob ash

| No. | 2-theta (°) | D (Å) | Height (cps) | FWHM (°) | Int. I (cps °) | Size (Å) |
|-----|-------------|-------|--------------|----------|---------------|----------|
| 1   | 21.022      | 4.2225| 4691         | 0.136    | 938           | 619      |
| 2   | 28.419      | 3.1381| 34625        | 0.087    | 4315          | 988      |
| 3   | 29.841      | 2.9917| 7414         | 0.145    | 1248          | 593      |
| 4   | 30.869      | 2.8944| 9215         | 0.157    | 1710          | 548      |
| 5   | 31.016      | 2.8810| 4571         | 0.121    | 655           | 710      |
| 6   | 40.582      | 2.2212| 21111        | 0.097    | 3064          | 915      |
| 7   | 50.236      | 1.8147| 4795         | 0.108    | 665           | 848      |

3.2. Physical properties analysis of the biocomposite boards

The results of density measurements from each variation of composite boards, namely P0, P1, P2, P3, P4, P5 were 0.958 g/cm$^3$, 0.935 g/cm$^3$, 0.972 g/cm$^3$, 0.984 g/cm$^3$, 0.980 g/cm$^3$, and 0.927 g/cm$^3$, respectively. P3 type composite board with 85% water hyacinth fibre content and 15% corncob ash showed the highest density. The higher the amount of corncob ash, the more it is possible to fill the empty voids in the composite. So that after mould was set, the resulting composite thickness tends to be lower, so the density of the P3 type composite board becomes higher, compared to other variations of composite boards. The moisture content of composite boards ranges from 7.78% to 10%, which were fulfilled the standards of JIS 5908:2003, which states that the maximum moisture content of particleboard is 13%.

The thickness swelling is related to water absorption, the more water that is absorbed and enters the board structure, the more dimensional changes are constructed. After immersion in water for 24 h, there
were no changes in board thickness, observed. All of the board samples showed very low water absorption so that there is no change in the board thickness. The composite board thickness swelling value has met the standards of JIS A 5908-2003 [8] and SNI 03-2105-2006 [9] which requires a thickness swelling value of less than 12%.

P0 type composite board which was composed of 100% water hyacinth powder produced the highest percentage of water absorption, which was 2.33%. While the lowest percentage of water absorption was found in P5 type composite board (100% corncob powder), which was 1.53%. This shows that the water hyacinth powder affects the value of the water absorption capacity of the composite board. The high content of water hyacinth powder in the composite board, initiate the increase of water absorption. The water absorption capacity of all composite board was also in accordance with the standard SNI 03-2105 [9] which is required to be a maximum of 50% [10].

The composite board endurance test was carried out by repeated soaking and drying treatments (cyclic treatment), showing that the composite board only experienced a minor change in mass, without a significant change in thickness. The results of cyclic treatment showed that, when the board was immersed or boiled in water, it increases the board mass by ±0.5-1 g. When the board was heated at 105°C for 4 h, the mass decreases by ±0.5-1 g (Figure 3). The cyclic treatment that has been carried out only affects minor changes in mass and does not affect changes in thickness. So, it can be concluded that the composite board is resistant to extreme conditions.

3.3. Mechanical properties analysis of the biocomposite boards

The mechanical properties of composite boards were evaluated by bending strength and compression strength analysis. Table 4 presents the values of bending strength and compression strength of various composite boards. The highest value of bending strength (MOR) and modulus of elasticity (MOE) were presented by P2 type composite board, which were 8.6 ± 0.31 N/mm² and 286.69 ± 5.9 N/mm², respectively. Whereas the highest compression strength value was demonstrated by P5 type composite board which was 2.94 ± 0.53 N/mm². On the other hand, P0 type composite board produces the lowest MOR, MOE and compressive strength values, namely 6.59 N/mm², 174.27 N/mm² and 2.01 N/mm², respectively (Figure 4). P2 type composite board which has a MOR value of 8.6 N/mm² has fulfilled the requirement by JIS A 5908 (2003) for particle board type 8, which is > 8 N/mm².
Table 4. Mechanical properties of biocomposite boards

| Boards | MOR (N/mm²) | MOE (N/mm²) | Compression strength (N/mm²) |
|--------|-------------|-------------|-----------------------------|
| P0     | 6.59 ± 0.54 | 174.27 ± 46.93 | 2.01 ± 0.1                 |
| P1     | 7.60 ± 0.65 | 215.42 ± 23.95 | 2.36 ± 0.03                 |
| P2     | 8.60 ± 0.31 | 286.69 ± 5.90  | 2.88 ± 0.08                 |
| P3     | 7.08 ± 0.34 | 271.65 ± 21.37 | 2.17 ± 0.11                 |
| P4     | 7.20 ± 0.47 | 213.99 ± 31.15 | 2.03 ± 0.15                 |
| P5     | 7.96 ± 0.26 | 247.96 ± 10.99 | 2.94 ± 0.53                 |

Figure 4. Mechanical properties of composite boards

In other study, binderless water hyacinth particleboards produced from pulp water hyacinth petiole or staple water hyacinth petiole shows bending strength of 0.548 MPa or 0.215 MPa, respectively [11]. Binderless particleboard, relying solely on hydrogen bonding between fibers, so its strength is not high. Therefore, adhesive is needed to produce high strength particleboards. Fiberboard made from oil palm empty fruit bunch fibers mixed with water hyacinth (50:50), using 13% urea formaldehyde (UF) or polymeric diphenylmethane diisocyanate (PMDI) resins, demonstrated 18.52 MPa and 25.47 MPa, respectively [13]. The main component in composite boards in this study was epoxy resin which was 90% from composite total weight. So that water hyacinth and corn cob have not been able to act as reinforcing materials but only act as fillers in composite boards.

Figure 5a shows that the water hyacinth fibre is still quite intact, even though it has been soaked in 5% NaOH for 2 hours. Corn cob powder, which is smaller in size, fills the gaps and empty spaces between the water hyacinth fibres and the epoxy (Figure 5b). The black spots in the Figure 5c shows the uneven distribution of corn cob ash in the epoxy composite.

Figure 5. Fracture of composite boards after bending test: (a) water hyacinth-epoxy composite, (b) water hyacinth (85%)-corn cob powder (15%)-epoxy composite, (c) water hyacinth (85%)-corn cob ash (15%)-epoxy composite, with 200x magnification
3.4. Thermal conductivity analysis of the cool box

Table 5 shows the results of the thermal conductivity value of composite boards P0 to P5, respectively, namely 0.569 W/mK, 0.531 W/mK, 0.305 W/mK, 0.613 W/mK, 0.621 W/mK, and 0.364 W/mK. The P2 type composite board produced the lowest conductivity value of 0.305 W/mK, not much different from the P5 type composite board which also has a low conductivity value of 0.364 W/mK. Meanwhile, the P4 type composite board has the highest thermal conductivity value of 0.621 W/mK, the same as P3 type which also has a high conductivity value of 0.613 W/mK. The value of the thermal conductivity (C) of a material shows the rate of heat transfer flowing in a material. The higher, the thermal conductivity value of the material, the more heat that flowing through the object. Therefore, a material with a large C value is a good heat conductor, whereas a material with a small C value is a poor conductor or an insulator.

| Boards | Water hyacinth powder (%) | Corncob ash (%) | Corncob powder (%) | C (W/mK) |
|--------|---------------------------|-----------------|-------------------|---------|
| P0     | 100                       | 0               | 0                 | 0.569   |
| P1     | 95                        | 5               | 0                 | 0.531   |
| P2     | 90                        | 10              | 0                 | 0.305   |
| P3     | 85                        | 15              | 0                 | 0.613   |
| P4     | 85                        | 0               | 15                | 0.621   |
| P5     | 0                         | 0               | 100               | 0.364   |

P2 type composite board which contains 90% water hyacinth powder and 10% corncob ash has the lowest thermal conductivity value. However, the thermal conductivity value is still not in accordance with the requirements for thermal characteristics as an insulator, which is in the range of 0.034-0.210 W/mK [14]. Density is one of the factors that affect the thermal conductivity of a material. If there are more pores in the material, the thermal conductivity will be smaller. Porous materials may contain gas in their pores. As it is known that gas is a poor heat transferor compared to liquids or solids [15]. Insulation material made from water hyacinth fiber and natural rubber latex with density range from 0.465 ~ 0.646 g/cm³ show thermal conductivity of 0.0246 ~ 0.0305 W/mK [16]. In other study, binderless water hyacinth particleboards produced from pulp water hyacinth petiole or staple water hyacinth petiole shows thermal conductivity of 0.065 W/mK or 0.047 W/mK, respectively [11]. The density of composite boards in this study, were quite high (0.927 g/cm³ ~ 0.984 g/cm³), that it affects the high thermal conductivity.

Corncob particles itself has higher thermal conductivity (0.109 W/mK) than of other natural fibers, namely barley straw (0.049 W/mK) or hemp shives (0.058 W/mK) [17]. In addition, the silica in corncob was thought to affect the thermal conductivity value. P4 type composite board which contains 15% corncob powder has the slightly higher conductivity value (0.621 W/mK) than of P3 type composite board which contain 15% corncob ash (0.613 W/mK). Whereas in P5 type which contains 100% corncob powder, shows lower thermal conductivity value (0.364 W/mK), almost as good as P2 type which contains 90% water hyacinth powder and 10% corncob ash (0.305 W/mK).

3.5. Thermal insulation effectiveness analysis

Based on the results of mechanical and thermal conductivity tests, P2 and P5 type composite boards demonstrated better test results compare to the others composite board. Therefore, in the effectiveness test, the cool box was made from P2 type composite board which had a composition of 90% water hyacinth powder and 10% corncob ash, and P5 type composite board which had a composition of 100% corncob powder. The composite cool box was made with size of 20x10x10 cm (2 L in volume) was filled with 1 kg
of ice block. For comparison, 2 styrofoam boxes were prepared which size of 25x19x9 cm (4.275 L in volume). The first styrofoam box was filled with 1 Kg ice block, whereas the second styrofoam box was filled with 2 Kg ice block. On the other hand, commercial cooler box (24 L in volume) was filled with 2 Kg ice block. The temperature measurement was carried out until the ice in the box has melted. The measurement results are shown in Table 6.

Data in Table 6 shows that the lowest temperature that can be achieved by P2 composite box was 19.3°C after 1-hour experiment, with the ambient temperature of 28°C. The ice in the P2 composite box had melted for 9 hours when the temperature inside P2 composite box was 25.9°C and the ambient temperature was 27°C. Meanwhile, the lowest temperature that can be achieved by P5 composite box was 18.8°C, after 3 hours experiment and the ambient temperature was 29°C. The experiment ended when the ice in the P5 composite box had melted for 9 hours at temperature inside P5 composite box of 24.9°C and the ambient temperature was 27°C.

| Table 6. Temperature monitoring inside and outside the cool box |
|---------------------------------------------------------------|
| Observation | Time | Temp in Composite Box (°C) | Temp in Styrofoam Box (°C) | Temp in Commercial Cooler box (°C) | Ambient temperature (°C) |
|-------------|------|---------------------------|---------------------------|---------------------------------|-------------------------|
|             |      | P2 (2 Kg ice) | P5 (1 Kg ice) | 1 Kg ice | 2 Kg ice | (2 Kg ice) | 1 Kg ice | 2 Kg ice | 1 Kg ice | 2 Kg ice |
| 1           | 10.30 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 |
| 2           | 11.30 | 19.3 | 19.0 | 16.4 | 13.5 | 13.7 | 28 |
| 3           | 12.30 | 20.9 | 19.3 | 17.1 | 14.3 | 13.1 | 27 |
| 4           | 13.30 | 19.9 | 18.8 | 17.5 | 13.7 | 13.5 | 29 |
| 5           | 14.30 | 20.6 | 18.9 | 16.2 | 14.0 | 13.6 | 29 |
| 6           | 15.30 | 20.6 | 18.9 | 16.3 | 13.9 | 13.6 | 28 |
| 7           | 16.30 | 22.1 | 19.8 | 16.3 | 14.1 | 13.7 | 28 |
| 8           | 17.30 | 22.9 | 21.4 | 16.3 | 14.1 | 13.7 | 27 |
| 9           | 18.30 | 24.5 | 23.3 | 16.6 | 14.3 | 13.3 | 27 |
| 10          | 19.30 | 25.9 | 24.9 | 17.9 | 14.3 | 13.3 | 27 |
| 11          | 20.30 | - | - | - | - | - | - | - | - | - |
| 12          | 21.30 | - | - | - | - | - | - | - | - | - |
| 13          | 22.30 | - | - | - | - | - | - | - | - | - |
| 14          | 05.30 | - | - | - | - | - | - | - | - | - |
| 15          | 07.00 | - | - | - | - | - | - | - | - | - |

The P2 and P5 composite box performance were still below the styrofoam box and commercial cooler box available in the market. This was because, styrofoam thermal conductivity (0.095 W/mK) [18] was lower compare with biocomposite box thermal conductivity, which were 0.305 W/mK and 0.364 W/mK for P2 and P5 composite box, respectively. In addition, the lid shape could not cover the biocomposite box properly. So that the biocomposite box could not lock the temperature.

4. Conclusions

Type P5 biocomposite boards with a composition of 100% corncob powder, showed the best physical properties compared with those of the other boards, which was the least weight change after repeated soaking and drying treatments. While the P2 type biocomposite board with a composition of 90% water hyacinth powder and 10% corncob ash showed the highest mechanical properties, namely bending and compression strength, and also demonstrated the best thermal insulating properties (thermal conductivity value of 0.305 W/mK) compared to those of other boards. The P2 boards complied with the standard of type
8 particle board according to JIS 5908:2003. However, the effectiveness of P2 and P5 boards in maintaining temperature was not significantly different.

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