# Influence of Resin Content and Density on Thickness Swelling of Three-layered Hybrid Particleboard Composed of Sawdust and *Acacia mangium*

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This study was carried out to determine the thickness swelling of three-layered hybrid particleboard composed of sawdust and *Acacia mangium* under two different testing conditions. The experimental particleboards, composed of mixed sawdust and *Acacia mangium*, were fabricated with different resin contents and densities within the face and back (both composed of sawdust) and the core (composed of *Acacia mangium* particles). Particleboards consisting of only *Acacia mangium* particles were used as the control. Three different resin ratios (8:10:8, 10:10:10, and 12:10:12) were tested in combination with three different board densities (500, 600, and 700 kg/m$^3$). Urea formaldehyde (UF), with the addition of wax, was used as a binder. The thickness swelling was evaluated using two tests: water immersion, and change in relative humidity, specifically between 10 and 90%, in accordance with the ASTM D 3502-76 (ASTM 1999) standard. The results indicated that there were significant interactions between the resin contents and the densities, which had an impact on the percentage of thickness swelling of the mixed sawdust-*Acacia mangium* composites in both test conditions.

*Keywords: Resin content; Density; Hybrid particleboard; Thickness swelling; Acacia mangium; Sawdust*

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## INTRODUCTION

The wood-based industry is an important industrial sector in Malaysia; however, the industry is a significant contributor to environment problems. The illegal dumping and open burning of wood waste and the inefficient use of timber and non-licensed incinerators on site are some factors that have contributed to the degradation of the surrounding environment (Wan Ariffin *et al.* 1999). In the future, it is expected that the wood sector will see higher costs for both timber and waste disposal. Under such circumstances, wood waste is expected to become a valuable resource. Rules and legislation have been imposed by the government to manage wood waste.

The use of wood residues in the production of particleboards has been considered environmentally sustainable, economically viable, and socially acceptable. Previous studies (dos Santos *et al*. 2013; da Silva *et al*. 2013; Pirayesh and Khazaeian 2012) have been shown that wood waste has the potential to be used to produce particleboard, which then can be used as a substitute resource in wood-based industries.

The dimensional changes that accompany the shrinkage and swelling of wood are major sources of both visual and structural problems in the final products of wood-based materials. Various finishes and treatments may be used to slow this process, but in general they do not stop it. According to Tsoumis (1991), the hygroscopicity properties might be associated with the chemical composition of the wood. Many studies (Hashim *et al*. 1997; Ellis and O'Dell 1999; Uysal 2005) have been carried out to dimensionally stabilize wood to prevent any of the problems associated with shrinkage and swelling; however, their success has been limited. Modifications of wood particles have been studied extensively to increase the water resistance in particleboard production (Bufalino *et al*. 2013; Ngueho Yemele *et al*. 2013). Besides wood particles, researchers also have focused on the development of binders that can help to reduce the hydrophobic nature of the particles.

This study was carried out to evaluate the thickness swelling rate of three-layered hybrid particleboards produced from sawdust and *Acacia mangium* under two different conditions: water immersion and relative humidity.

## EXPERIMENTAL

### Preparation of Samples

Sawdust was obtained from the Wood Processing Laboratory, UiTM Jengka, Pahang, Malaysia. The mixed sawdust contained particles of various sizes produced during wood processing. The sawdust was screened for removal of the fine particles, and the particles that measured ≥ 0.5mm were air-dried. *Acacia mangium,* which was obtained from the forest plantation UiTM Jengka, Pahang, Malaysia, was harvested and debarked before being chipped to pieces measuring 3 to 5 cm. A juvenile *Acacia mangium*, aged approximately five to seven years, was used. Next, the chips were put into ring flakers for the production of particles of sizes on average smaller than 5.0 mm. After being air-dried, the particles were screened for the desired size, 2 mm. The sawdust and *Acacia mangium* particles were then oven-dried at 90±5 $^{o}$C until the desired moisture content, ≤4%, had been reached. Urea formaldehyde (UF) was used as a binder. The UF was supplied by MAC, Shah Alam, Selangor, Malaysia. UF was used with addition of 1% wax based on the oven dried particles. The three-layered hybrid composites composed of sawdust and *Acacia mangium* were fabricated with several different resin contents and densities within the face and back (both composed of sawdust) and core (composed of *Acacia mangium* particles). Three-layered *Acacia mangium* particleboards were also prepared as a control.

Three different resin ratios (8:10:8, 10:10:10, and 12:10:12) were combined with board densities of 500, 600, and 700 kg/m$^3$. The dried particles were put into a mixer, and before they were mixed, the amount of resin required for each board was calculated. A 350 mm x 350 mm mold was used. The mats were pre-pressed at 1.034 N/mm$^2$ for 2 min. The mats were then placed in a hot press, a process that only accommodates one sheet at a time. The temperature was set at 185 °C for 6 min. Next, the panels were exposed to room temperature for about 4 to 6 min before being placed in the conditioning room.

### Properties of Thickness Swelling

Thickness swelling (TS) is composed of two different factors, water immersion performance and dimensional changes resulting from changes in relative humidity from 10 to 90%, tested according to the ASTM D 3502-76 (ASTM 1999) standard. For the water immersion test, samples were cut that were 50 mm long by 50 mm wide and of particleboard panel thickness. For each type of board, 30 replicates were generated. The specimens were oven dried at 103 ± 2 $^oC$ for 24 h, and measurements of thickness and weight were obtained. The thickness measurement was taken at three different points on the boards. The specimens were then submerged such that the top face of each specimen was about 2.5 to 3.0 cm from the surface of the water. The temperature of the water used was set in an atmosphere of a relative humidity of 65 ± 5% and a temperature of 25 ± 2 $^oC$. Care was taken to ensure that the specimen faces were not resting against the flat surface of the container. Every two hours of submersion, the specimens were removed, extra water on the surface of the specimens was wiped off, and measurements of weight and dimension were obtained. The same procedure was repeated for 24 h until the measurements (thickness swelling and weight) were constant. According to ASTM D 3502-76 (ASTM 1999), thickness swelling is calculated as a percentage (%) using the equation,

$$TS\ (\%) = [(T_0 - T_i) / T_i] \times 100 \quad (1)$$

where $TS$ is thickness swelling (%), $T_0$ is wet thickness after water saturation for 2 until 24 hours (mm), and $T_i$ is oven dried thickness (mm)

To study the dimensional properties at different levels of relative humidity (RH), the study was carried out in an RH chamber, a Salt Solution Humidity Chamber (LEEC). This study was run based on work by Hashim *et al.* (1997) and other previous studies, with some modifications on the sample's size. Ten replicates of the test panels, each measuring 60 mm long by 20 mm width and having the thickness of the board, were cut from each type of board. The specimens were exposed to different levels of RH to evaluate their absorption and desorption properties. The first cycle started at 11.3% and was increased successively to 22.5%, 32.8%, 52.89%, 68.86%, 75.3%, and 97.3%; the RH was decreased successively to 68.86%, 32.8%, and 22.5%.

The specimens were then exposed in the RH chamber until the weight was constant before being shifted to the next level of RH. After two weeks, the specimens were removed, and measurements of their weights and dimensions (length, width, and thickness) were obtained. The same procedure was repeated until the cycle level of RH was completed. Finally, after reaching the last level of RH, the specimens were oven-dried at 105±2$^oC$ for 24 h, and the measurements were then obtained. One-way Analysis of variance (ANOVA) was used to determine whether there were significance differences among boards with different resin contents and densities.

## RESULTS AND DISCUSSION

Figures 1, 2, and 3 show the thickness swelling (TS) rates of (a) the hybrid particleboards and (b) the *Acacia mangium* particleboards at densities of 500,600, and700 $kg/m^3$and with resin ratios of 8:10:8, 10:10:10, and 12:10:12.

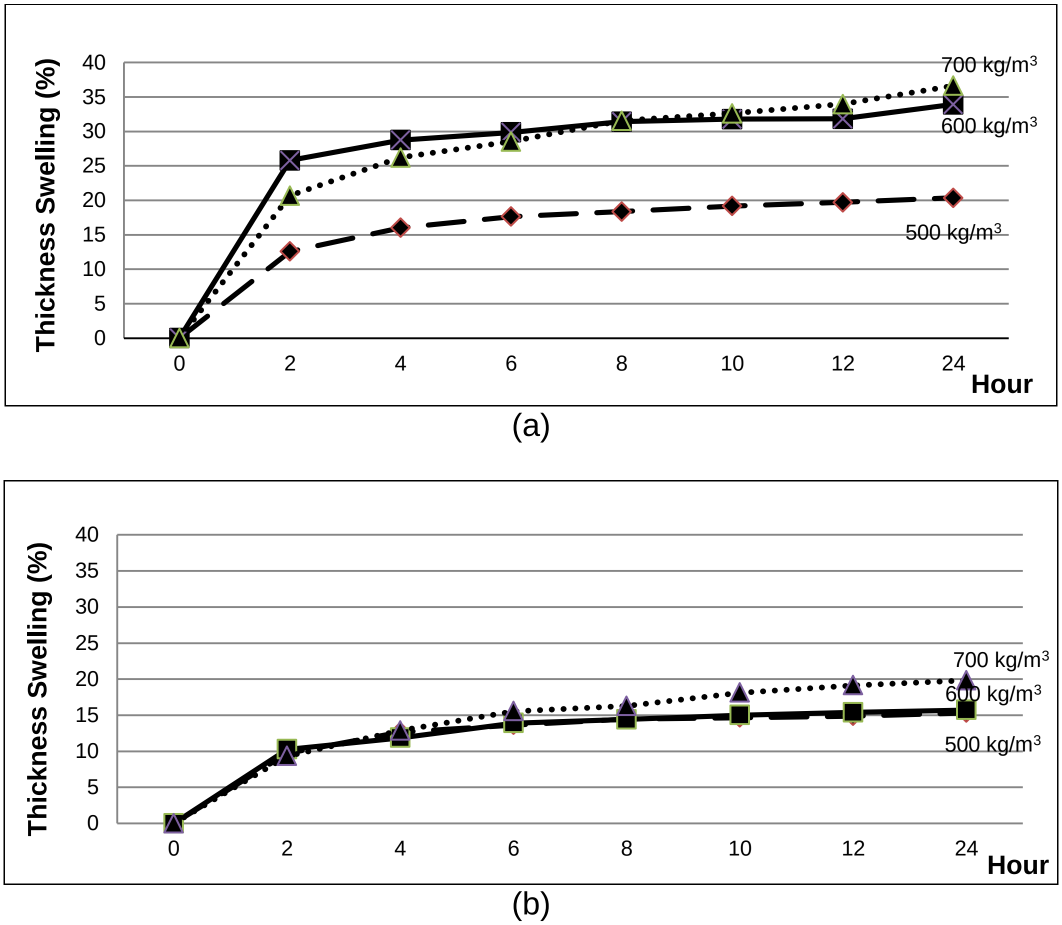
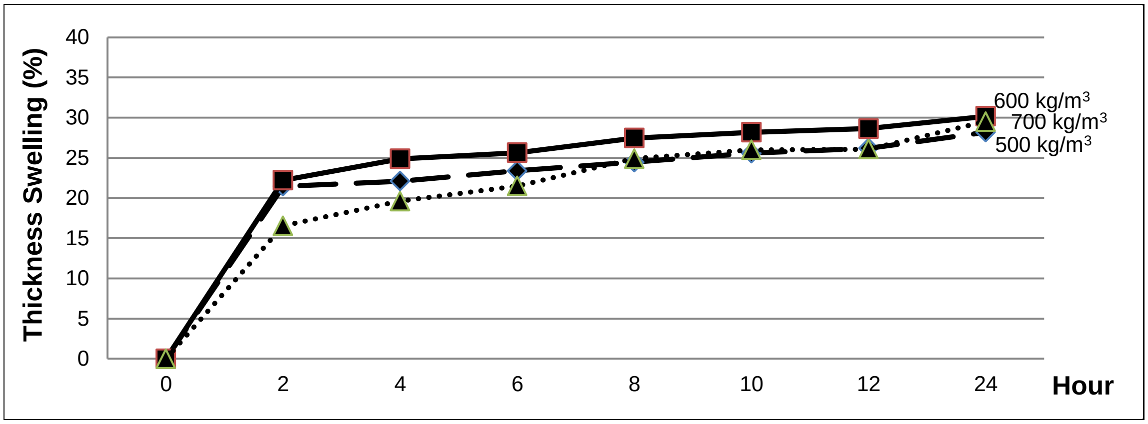
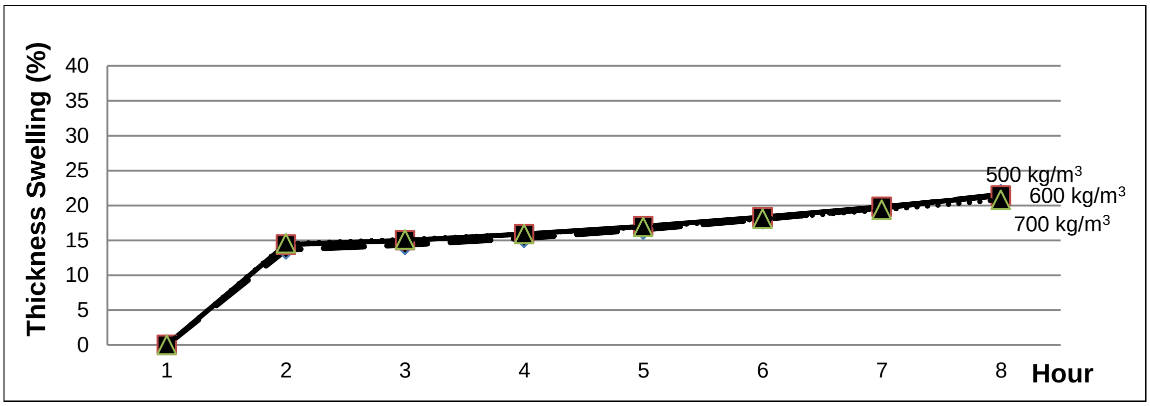



**Fig. 1.** Thickness swelling rate with water immersion of (a) hybrid particleboards and (b) *Acacia mangium* particleboards at densities of 500, 600, and 700 kg/m$^3$ with a resin ratio of 8:10:8

At resin ratios of 8:10:8, on average, the TS rate was higher for the hybrid particleboards than for the *Acacia mangium* particleboards. As far as densities, the results indicated that the TS rates of both the hybrid and *Acacia mangium* particleboards were higher at 700 kg/m$^3$ than at 500 or 600 kg/m$^3$. In Fig. 1(a), it can be seen clearly that the density of 500 kg/m$^3$produced the lowest TS rate, while according to Fig. 1(b), the TS rate was almost equal to and only slightly higher (5%) for the particleboards tested at a density of 700 kg/m$^3$. As can be seen in Fig. 2(a) and (b), the TS rates were in about the same range for all three densities (500, 600, and 700 kg/m$^3$). However, the TS rates were higher for the hybrid particleboards. Compared to the particleboards with a resin ratio of 8:10:8 (Fig. 1), the TS rates of particleboards produced with a resin ratio of 10:10:10 were lower, with a difference of 7% for all three densites.

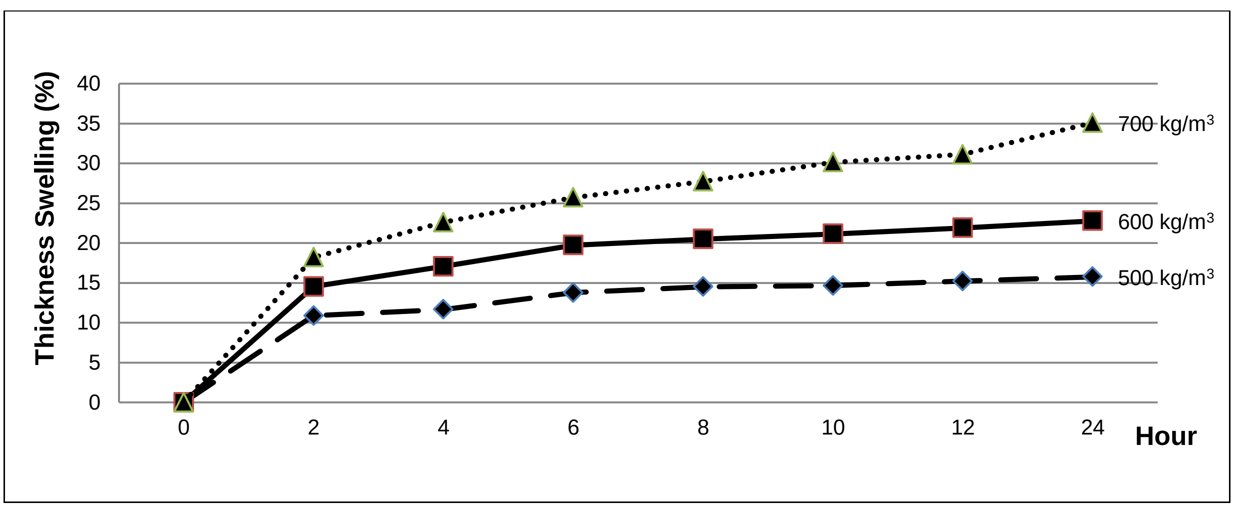



(a)



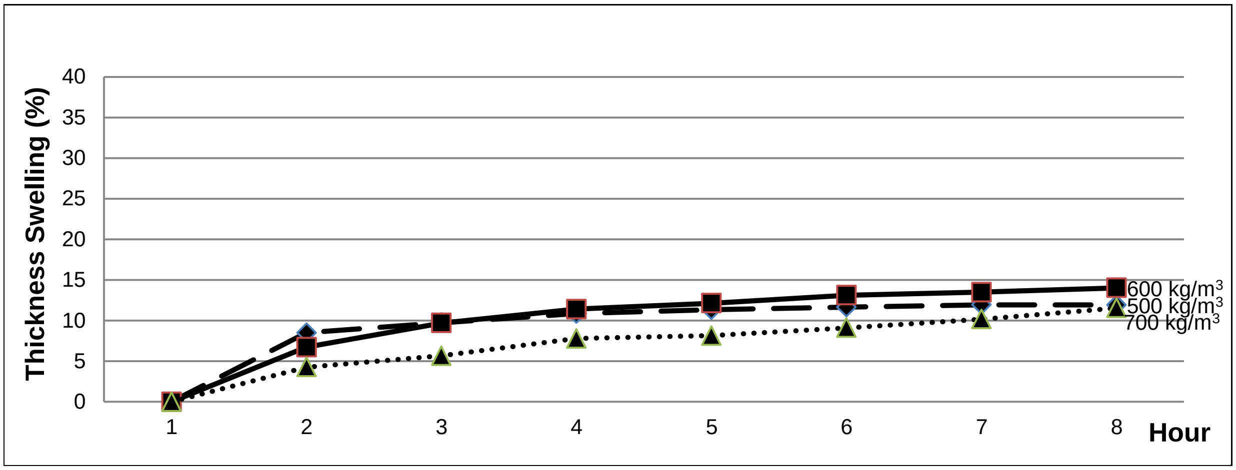

(b)

**Fig. 2.** Thickness swelling rate with water immersion of (a) hybrid particleboard and (b) *Acacia mangium* particleboard at densities of 500, 600, and 700 kg/m$^3$ with a resin ratio of 10:10:10




(a)

**Fig. 3a.** Thickness swelling rate with water immersion of hybrid particleboard with densities of 500, 600, and 700 kg/m$^3$ with a resin ratio of 12:10:12




(b)

**Fig. 3b.** Thickness swelling rate with water immersion of (a) hybrid particleboard and (b) *Acacia mangium* particleboard with densities of 500, 600, and 700 kg/m$^3$ with a resin ratio of12:10:12

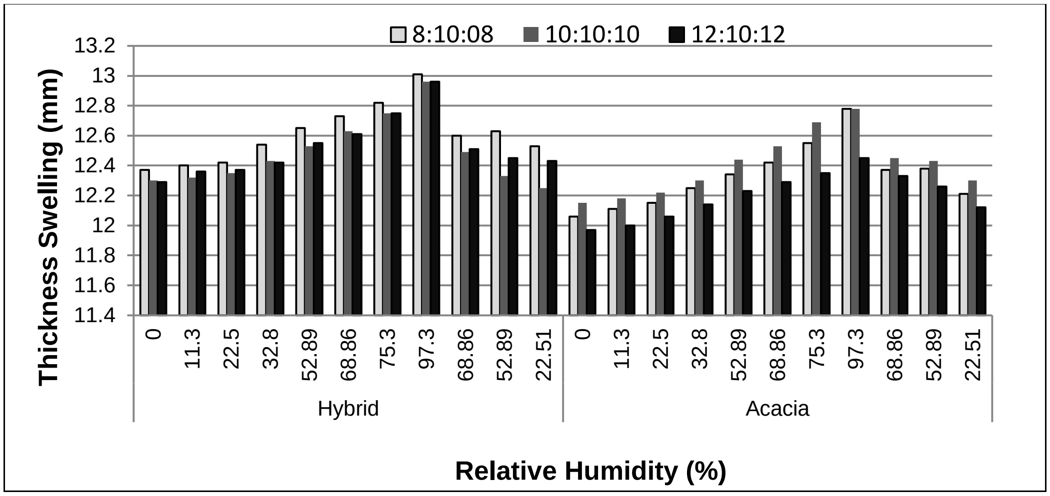
As can be seen in Fig. 3, the TS rates were different for the 8:10:8 *versus* the 10:10:10 resin ratios (Figs. 1 and 2). The TS rates for the hybrid particleboards increased in parallel with the increase in density; the opposite was observed for the TS rate for *Acacia mangium* particleboards. For the hybrid particleboards, the highest TS rates were recorded for the 700 kg/m$^3$ density boards, followed by the 600 kg/m$^3$ boards, with the 500 kg/m$^3$ boards as the lowest. The poor performances are attributed to the hydrophilic nature of sawdust itself. Moreover, wood is a hygroscopic material that attracts water from the surrounding atmosphere. The higher the density of the panels is, the higher the mass of the sawdust that was used.

Figure 4 shows the TS rates with the changes in relative humidity of the hybrid and *Acacia mangium* particleboards.

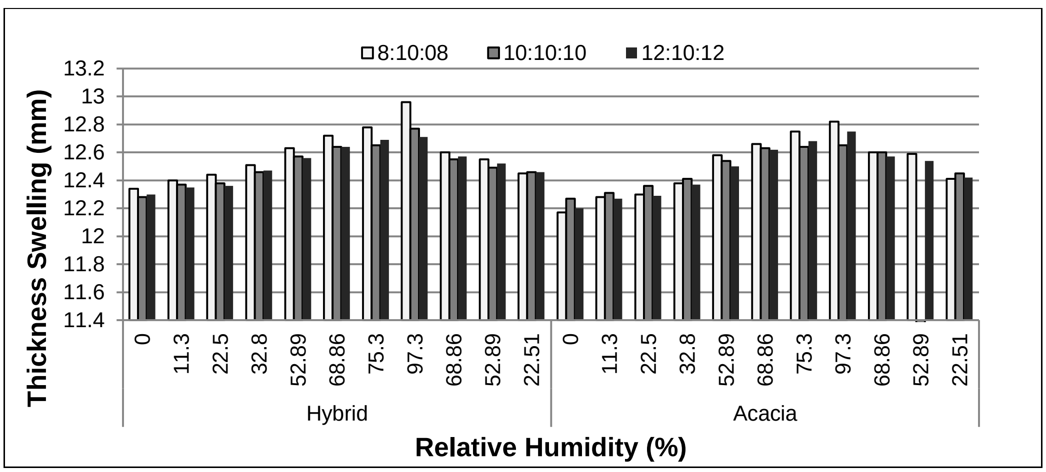
As shown in Fig. 4, when the relative humidity (RH) was increased, the TS of the panels increased. This was observed for both hybrid and *Acacia mangium* particleboards at all three densities. Of the particleboards with different densities, the TS rates of the particleboards with densities of 600 kg/m$^3$ were almost stable between the different RH levels and did not have any significant differences.

With respect to the resin content, at all three densities and for both types of particleboard, the TS rate of the particleboards bonded at the resin ratio of 8:10:8 was the highest, followed by those of 10:10:10 and 12:10:12. The resin ratio affected the performance properties of the panels. When the resin content was increased, the performance of the panels improved. This might have been due to the resin itself, which filled the void among the particles and thereby reduced the moisture uptake from the environment (Sarmin *et al.* 2013).

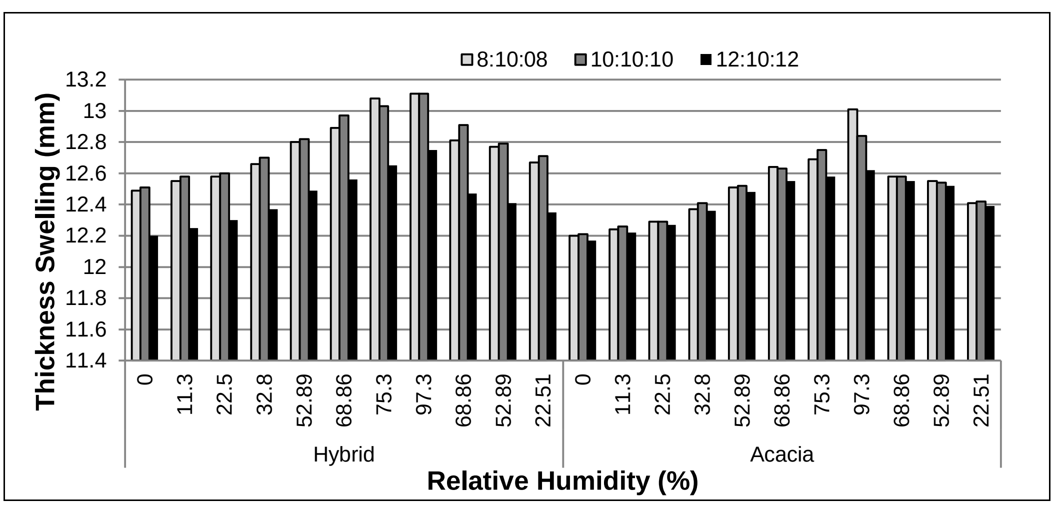
The ANOVA produced a *p*-value that was <0.0001 for all variables, which was less than 0.05 and therefore indicated that the impact of the resin contents and densities on the TS rates was significant for both hybrid and *Acacia mangium* particleboards.




(a)




(b)




(c)

**Fig. 4.** Thickness swelling rate with changes in relative humidity of hybrid and *Acacia mangium* particleboards with densities of (a) 500 kg/m$^3$, (b) 600 kg/m$^3$, and (c) 700 kg/m$^3$ with resin ratios of 8:10:8, 10:10:10, and 12:10:12.

## CONCLUSIONS

1. The thickness swelling rates of hybrid particleboards bonded at different resin ratios (8:10:8, 10:10:10, and 12:10:12) and at different densities (500, 600, and 700 kg/m$^3$) were comparable to those of *Acacia mangium* particleboards.
2. The panels with the resin ratio of 12:10:12 showed better thickness swelling rates compared to those with resin contents 8:10:8 and 10:10:10, in terms of both water immersion and dimensional changes associated with changes in relative humidity.
3. On average, the thickness swelling rates of panels produced with densities of 600 kg/m$^3$ were better than those of panels produced with densities of 500 and 700 kg/m$^3$ for all three resin ratios and for both hybrid and *Acacia mangium* particleboards.
4. Sawdust can be commercialized and used to produce value-added products that at the same time minimize waste from the industry. A further study of sawdust properties in relation to developed alternative materials in the wood-based industry is needed.

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