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# Properties of Binderless Particleboard and Particleboard with Addition of Urea Formaldehyde Made from Oil Palm Trunk Waste

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**ABSTRACT:** *Malaysia produces a large amount of oil palm biomass yearly especially in the form oil palm trunks. The purpose of this research was to convert oil palm trunk waste into value-added panels namely particleboard. Binderless particleboards and particleboards with addition of 10% urea formaldehyde were made from oil palm trunk particles at higher thickness levels. Particleboards were manufactured at two thickness levels namely 10 mm and 15 mm at target density of 0.8 g cm$^{-3}$. Physical and mechanical properties of particleboards including density, thickness swelling, water absorption, modulus of rupture and internal bond strength were determined. Moreover, properties of oil palm trunk particleboard were characterised in terms of thermal analysis by thermogravimetric analyses (TGA) and morphological analysis by scanning electron microscopy (SEM). Based on the results obtained, particleboards with addition of urea formaldehyde exhibited higher physical and mechanical properties in comparison to binderless particleboards at each thickness levels. On the other hand, particleboard of 10 mm in thickness showed better properties than particleboards of 15 mm in thickness except for modulus of rupture. The mechanical properties of all types of boards have met the minimum requirement of Japanese Industrial Standard for Type 8. The overall results revealed that addition of minimal amount of urea formaldehyde as adhesive can improve the basic properties of oil palm trunk particleboard.*

**Keywords:** Oil palm trunk, particleboard, physical properties, mechanical properties, oil palm biomass

## 1. INTRODUCTION

Malaysia is one of the largest producers of palm oil in the world with huge areas of oil palm plantation. The palm oil has a high demand in many countries as it can be used for various applications including in food such as cooking oil and margarines, and also in non-food industries such as detergents, shampoo and biofuel.[1] Consequently, a large amount of waste has been generated from oil palm plantation due to high-value utilisation of palm oil. Other parts of oil palm tree namely trunk, fronds and empty fruit bunch are considered a solid waste once they reach economic life span of 25 years.[2]

Wastes obtained from oil palm plantation give rise to environmental issues due to improper disposal of the residues such as open burning which leads to major air pollution. Since a massive amount of solid waste is generated yearly, they can be utilised efficiently and effectively for production of value-added products such as fibre-based products, wood-based composite products and building construction, as well as sources of energy.[3]

With a limited supply of wood material arising from depleting forest resources, wood-based industry is searching for wood substitute. Utilisation of waste from oil palm plantations will solve the demand for wood materials and thus reduce disposal of those wastes. Many studies have been conducted to explore new usage of oil palm waste especially for wood-based panels, where it has been utilised as raw materials for particleboard, plywood and fibreboard production.[4]

The intention of particleboard without addition of any adhesive is an alternative way to reduce and eliminate the use of synthetic resin and to produce an environmentally friendly product. Furthermore, much effort has been put on utilisation of agricultural waste or lignocellulosic materials from oil palm trunk, kenaf fibre, empty fruit bunch and also coconut husk.[5] Hashim et al. have explored utilisation of oil palm trunk for the production of binderless particleboard where it can emit usage of synthetic adhesive which is hazardous to human health.[6] However, the basic properties of oil palm trunk binderless particleboard still need improvisation.

In this study, urea formaldehyde was added as adhesive at a low percentage to improve the basic properties of oil palm trunk particleboard in comparison to binderless boards. Furthermore, particleboard of higher level of thickness was manufactured to diversify its end product purpose. Baskaran et al. have successfully manufactured boards at higher thickness levels.[7] However, in this study, the influence of urea formaldehyde on higher thickness levels oil palm trunk particleboard was investigated.

## 2. EXPERIMENTAL

Raw materials used for particleboard production in this study are oil palm trunk particles which were supplied by Encore Agricultural Industries Sdn Bhd. Oil palm trunk particleboards were manufactured at two thickness levels of 10 mm and 15 mm with two different conditions namely binderless particleboard and particleboard with addition of urea formaldehyde at a target density 0.80 g $cm^{-3}$.

Oil palm particles were weighted and placed into a mould with dimension 20.5 cm × 20.5 cm followed by pre-pressing for 3 min to form a mat at target thicknesses of 10 mm and 15 mm. Unlike binderless particleboard, particleboard with addition of urea formaldehyde were manufactured with addition of 10% of urea formaldehyde adhesive, which were calculated based on air dried weight of oil palm trunks, was mixed manually with oil palm particles before formed into mat. The mat was pressed at manufacturing condition at a pressure of 5 MPa and temperature of 180°C for 20 min.[7] A total of 24 single-layer particleboards where 6 replicates were manufactured for each type of particleboards.

### 2.1 Testing of Particleboards

Physical and mechanical properties of boards that were carried out include density, thickness swelling and water absorption, modulus of rupture and internal bond strength according to Japanese Industrial Standard JIS A 5908: 2003 Particleboard.[8] Three specimens from each board with the dimension of 5 cm × 5 cm were used to determine thickness swelling and water absorption by soaking them in water for 24 h. The thickness of each specimen was measured before and after water soaking at four points of midway along each side and 1 cm from the edge at accuracy of 0.01 mm. One specimen for modulus of rupture and three specimens for internal bond strength with the dimension of 5 cm × 15 cm, and 5 cm × 5 cm respectively were prepared from each type of board for the evaluation of mechanical properties. Both tests were done on an Instron Testing System Model UTM-5582 equipped with a load cell capacity of 1000 kg.

### 2.2 Thermal Analysis

The thermogravimetric analysis (TGA) analysed thermal stability of materials at different temperatures were conducted using a Perkin Elmer TGA 7 thermogravimetric analyser. Scans were recorded from 30°C to 800°C for samples of 5–10 mg placed in an aluminium pan with a heating rate of 20°C $min^{-1}$ under a nitrogen atmosphere.

### 2.3 Morphological Analysis

Scanning electron microscopy (SEM) was employed to analyse morphological structure of oil palm trunk particles between binderless particleboard and particleboard with addition of urea formaldehyde. Micrographs were taken from cross sections of 0.5 cm × 0.5 cm of experimental panels. The samples were coated with gold by an ion sputter coater (Polaron SC515, Fisons Instruments, UK). A Scanning Electron Microscope LEO Supra 50 Vp, Field Emission SEM, Carl-Zeiss SMT, Oberkochen, Germany was employed for microscopic study.

## 3. RESULTS AND DISCUSSION

### 3.1 Evaluation on Water Absorption and Thickness Swelling

The physical properties, namely thickness swelling and water absorption of binderless particleboard and particleboard with addition of urea formaldehyde are shown in Table 1 which was evaluated by Tukey Test. Based on the result obtained in Table 1, binderless particleboard with thickness of 15 mm had the highest water uptake compared to other boards. The water absorption values of binderless particleboard improved as the addition of urea formaldehyde in the oil palm trunk particleboard. The values significantly reduced by 4.86% and 12.95% for particleboard with addition of urea formaldehyde at thickness levels of 10 mm and 15 mm respectively. Thickness swelling of the boards with 10 mm in thickness reduced significantly to 21.93% while 55.28% for boards in 15 mm in thickness when the addition of urea formaldehyde compared to binderless particleboard.

Table 1: Physical and mechanical properties of binderless particleboard (B) and particleboard with addition of urea formaldehyde (U).

| Types of boards | Density (g cm$^{-3}$) | Thickness swelling (%) | Water absorption (%) | Modulus of rupture (MPa) | Internal bond strength (MPa) |
|---|---|---|---|---|---|
| 10 B | 0.80 (0.015) | 40.08 (4.68)$^{b}$ | 83.45 (11.42)$^{b}$ | 8.08 (1.15)$^{a}$ | 0.84 (0.41)$^{a,b}$ |
| 10 U | 0.80 (0.009) | 32.87 (5.71)$^{a}$ | 79.58 (11.31)$^{a}$ | 10.28 (1.18)$^{b}$ | 1.44 (0.64)$^{c}$ |
| 15 B | 0.80 (0.011) | 51.63 (6.18)$^{c}$ | 98.31 (12.19)$^{c}$ | 13.05 (1.35)$^{c}$ | 0.64 (0.54)$^{a}$ |
| 15 U | 0.80 (0.010) | 33.25 (5.44)$^{a}$ | 87.04 (12.25)$^{b}$ | 15.20 (1.20)$^{d}$ | 1.20 (0.61)$^{b,c}$ |

*Notes: 10 and 15 represent thickness levels; values in parenthesis are standard deviation; different letters in superscript represent statistical significance while same letters indicate a similarity of differences ($p < 0.05$).*

The rate of water absorption in particleboard also depends on the board thickness. The higher thickness boards have higher percentage of water uptake. Besides that, there is a significant increase of 28.82% for water absorption and 17.81% for thickness swelling as increasing thickness of oil palm binderless particleboard.

Oil palm trunk is a highly hygroscopic material which can absorb higher moisture from the surroundings.[9] Hence, the absorption of water by particleboard was affected by the hygroscopic properties of oil palm trunk. However, the percentage of water uptake was lower for particleboards with addition of urea formaldehyde. The porosity of the boards was reduced by addition of urea formaldehyde resin. The particles that have been pressed and show high compaction level are attributed to low water penetration and diffusion into the boards, as the particleboards have low capacity to absorb water.[10]

### 3.2 Evaluation on Modulus of Rupture

Modulus of rupture of all particleboards met the requirement of the Japanese Industrial Standard for Type 8.[8] The values improved with the presence of urea formaldehyde and also higher thickness. As can be seen in Table 1, modulus of rupture values increase significantly by 27.23% for board of 10 mm in thickness and 16.48% for board of 15 mm in thickness as addition of urea formaldehyde in comparison to binderless particleboard. Whereas, a significantly increase of 61.48% and 47.86% were found as increasing thickness level for binderless particleboard and board with addition of urea formaldehyde.

The binderless particleboard had lowest bending strength because the strength of board was attributed by self-bonding process only. Moreover, types of raw material also affect the strength values since oil palm trunk has lower strength values.[6] Thus, addition of adhesive like urea formaldehyde can form a strong fibre contact within oil palm particles. It is revealed from the result obtained where boards with addition of urea formaldehyde have high modulus of rupture values.

### 3.3 Evaluation on Internal Bond Strength

The internal bond strength for particleboard with addition of urea formaldehyde was higher than binderless particleboard. The values increased significantly as addition of urea formaldehyde with 71.43% and 87.50% for particleboard with thickness level of 10 mm and 15 mm respectively as shown in Table 1. Urea formaldehyde enhanced the bonding between particles and fibres especially during hot pressing process. Internal bond values reduced as increasing thickness level of board. Particleboard of 10 mm in thickness with addition of 10% urea formaldehyde has highest internal bond strength. High compaction ratio between oil palm particles at lower thickness and also addition formaldehyde based adhesive improved bonding between raw materials resulted in high mechanical properties. The higher internal bond was contributed by high cellulose content and moderate lignin content of oil palm trunk samples.[11] All types of particleboard made from oil palm trunk have exceeded the minimum requirement of Japanese Industrial Standard for Type 8.[8]

## 3.4 Evaluation on Thermal Degradation

The thermal degradation for binderless particleboards and particleboards with addition of urea formaldehyde are shown in Figure 1. Figure 1(a) represents the weight loss curve (TG) and Figure 1(b) represents derivative thermogravimetric (DTG) profiles. The curves show that the weight starts to decreased when the temperature is increased between 200°C and 300°C. This is because the materials begin to absorb the heat energy.[12]

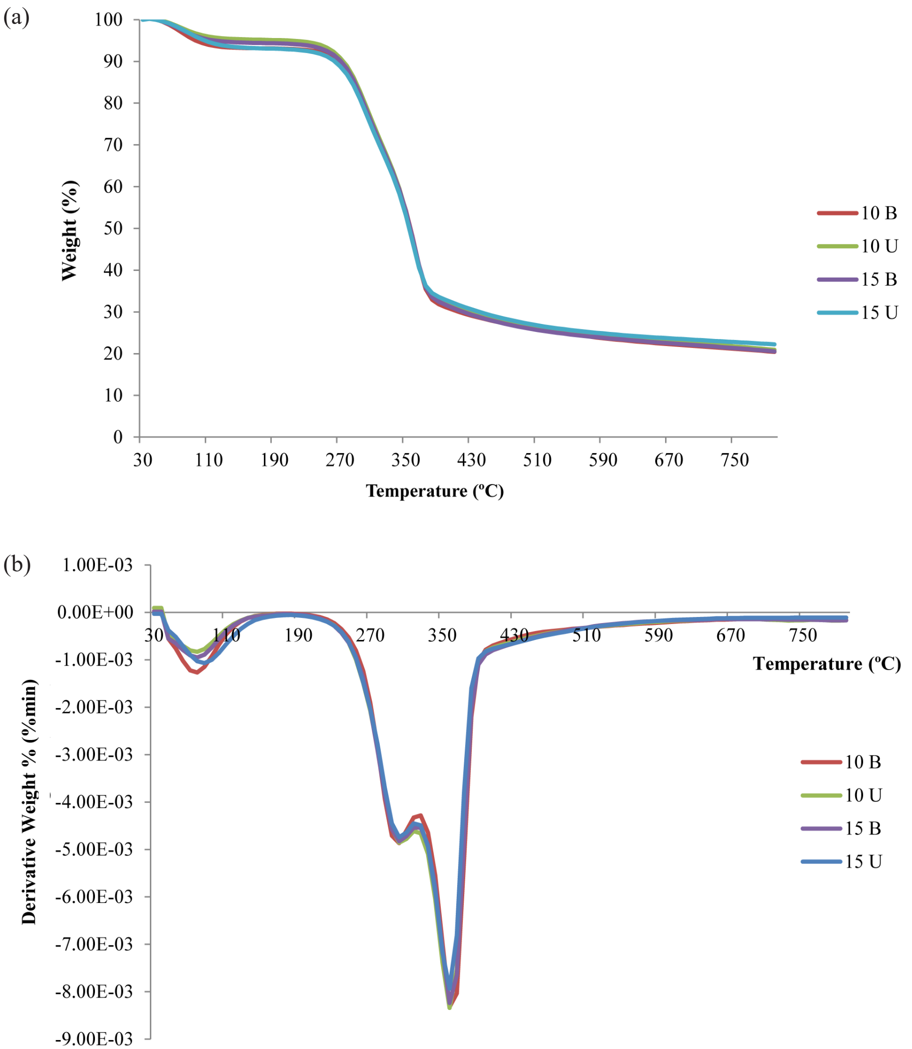


Figure 1: (a) TG and (b) DTG curve of binderless particleboard (B) and particleboard with addition of urea formaldehyde (U) at different thickness levels of 10 mm and 15 mm.

The weight loss in binderless particleboard is lower compared to board with addition of urea formaldehyde. This indicates that urea formaldehyde has good structural stability. It can be concluded that binderless particleboard thermally degraded faster compared to particleboard with addition of urea formaldehyde. Particleboard with addition of urea formaldehyde takes slightly longer time to degrade as the oil palm particles are bonded together with urea formaldehyde. Hence, the presence of adhesive produces stronger crosslinking of hydrogen bond and hard to be broken. As a result, the degradation of materials required more heat energy. The peak temperature shows where the maximum weight loss occurs. First and foremost, hemicellulose will degrade followed by cellulose. Compared to hemicellulose and cellulose, degradation of lignin required a longer period of time to ensure the decomposition is complete.[13]

## 3.5 Evaluation on Morphological Properties

The morphological properties of binderless particleboard and particleboard with addition of urea formaldehyde can be observed from SEM analysis as illustrated in Figure 2.

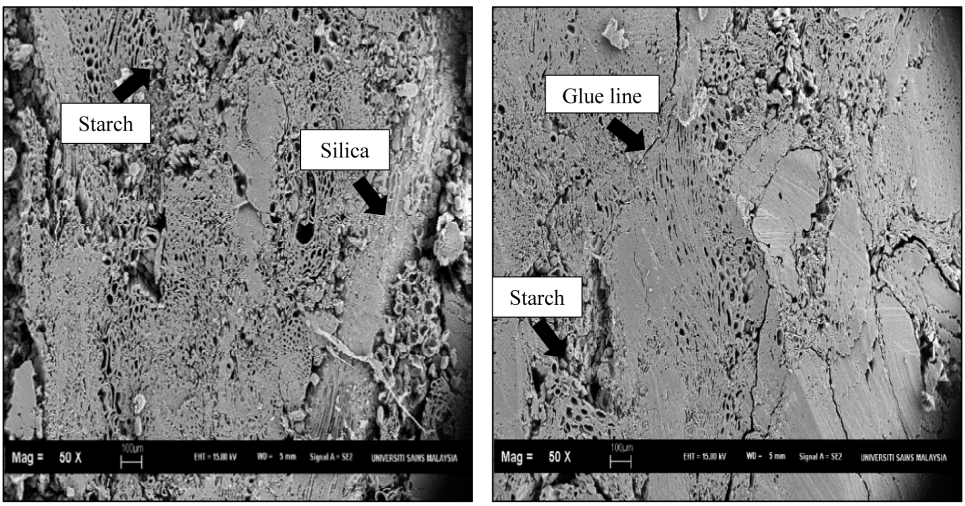


Figure 2: Micrographs of binderless particleboard (left) and particleboard with addition of urea formaldehyde (right).

From Figure 2, compressed cell walls and fibres of oil palm trunk can be seen clearly from the micrograph. This is due to high pressure applied during hot pressing when particleboard was manufactured. Hot pressing helps adhesive to melt and disperse evenly within the oil palm particles. Besides, adhesive caused the particles to become bonded together and more bonding are formed. Hence, particleboard with addition of urea formaldehyde has greater compactness compared to binderless particleboard. The presence of urea formaldehyde can be clearly seen as glue line in particleboard with addition of urea formaldehyde at high magnification level in Figure 2(b). The presences of silica in the samples with addition of urea formaldehyde were found in both thickness levels namely 10 mm and 15 mm. Besides that, the starch in oil palm trunk also can be detected from the Figure 2.

## 4. CONCLUSION

Properties of binderless particleboard and particleboard with addition of urea formaldehyde at two different levels of thickness, namely 10 mm and 15 mm were investigated. Based on the result, urea formaldehyde was found to be a potential adhesive as it improved physical and mechanical properties of oil palm trunk particleboard at each level of thickness. Besides, the mechanical properties of all types of board have met the minimum requirement of Japanese Industrial Standard for Type 8 which should have internal bond strength of 0.15 MPa in minimum and modulus of rupture of 8.0 MPa in minimum. Particleboard of 10 mm in thickness showed better properties than particleboards of 15 mm in thickness except for modulus of rupture. Therefore, higher thickness boards are more suitable for lower strength application. The addition of 10% of urea formaldehyde improved physical, mechanical, thermal and morphological properties of oil palm trunk particleboard. As conclusion, oil palm trunk biomass especially oil palm trunk particles have a great potential to be used in wood-based composites product especially for interior applications such as frame, cupboard, table, chair and accessories. Moreover, it can help to minimise waste and conserve the environment by producing binderless particleboard with higher thickness levels.

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