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SHORT NOTE

ADDITION OF PROPYLAMINE AS FORMALDEHYDE SCAVENGER FOR UREA FORMALDEHYDE-BONDED PARTICLEBOARD

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ABSTRACT

Rubberwood particleboard were produced using urea formaldehyde (UF) resin admixed with propylamine as formaldehyde scavenger. 1 % propylamine were incorporated into 8 %, 10 %, 12 %, 14 % and 16 % UF resins, respectively. The effectiveness of propylamine addition to reduce formaldehyde emission from particleboard was examined. Physical and mechanical properties were evaluated according to Japanese Industrial Standard (JIS). The results showed that addition of propylamine had reduced 33 to 65 % formaldehyde emission from particleboard made with different dosages of UF resin. However, the properties of the particleboard were adversely influenced by the addition of propylamine. Higher resin dosage (≥14 %) had counterbalanced the loss of strength and dimensional stability but accompanied by increased formaldehyde emission. As a conclusion, UF dosage of 14 % admixed with 1 % propylamine is the most ideal formulation to produce particleboard with low formaldehyde emission while maintaining the desired properties.

KEYWORDS: Formaldehyde emission, formaldehyde scavenger, particleboard, propylamine, urea formaldehyde resin.

INTRODUCTION

As one of the most important forest products, production volume of particleboard keep increasing worldwide (Gűler et al. 2016). Up until now, application of urea formaldehyde (UF) resin is still a very prevalent practice in wood-based industry, particularly in particleboard manufacturing. The reasons of UF resin become a favoured by binding agents in particleboard manufacturing are mainly due to its cheap price and high reactivity (Moslemi 1974). Unfortunately, UF resin is instable at high relative humidity along with elevated temperature due to its susceptible aminomethylene linkage. In addition, hydrolysis of methylene ether bridge in high relative humidity state generate a permanently release of formaldehyde from wood-based panels (Dunky 1998). Formaldehyde gas emitted from UF-bonded particleboard is a primary indoor pollutant and could be detrimental to user's health (Moubarik et al. 2013). Therefore, plenty of efforts has been conducted by manufacturers and researchers in recent years with the purpose of reducing the emission of formaldehyde from wood-based products to meet the global low emission market, for example, Japan.

Japanese market is very important to Asian countries and therefore the local production line is persistently influenced by the Japanese trends. According to Japanese Industrial Standard (JIS), only wood panels with emission level of F**** (≤ 0.3 mg/L) could be used unrestrictedly within room, while the F*** (≤ 0.5 mg/L) and F** (≤ 1.5mg/L) panels are only allowed provided that the room is spacious and have good ventilation (Eastin and Mawhinney 2011). According to Athanassiadou and Ohlmeyer (2009), the respective emission level of F****, F*** and F** are more or less equivalent to European standard's SE0, E0 and E1. In order to achieve the emission level stated above, numerous method had been conducted and the most effective and convenient way is to incorporate the formaldehyde scavenger into the UF resin followed by directly apply on the wood furnish (Lum et al. 2014; Zaidon et al. 2016). The most widely used formaldehyde scavengers in the particleboard industry is ammonium salt and urea whereas other chemicals that can bind with the free formaldehyde existing in the resin are also being used (Puttasukkha et al. 2015).

Addition of amine compounds as formaldehyde scavenger in the production of urea formaldehyde-bonded medium density fibreboard (MDF) had been reported by Boran et al. (2011). The study revealed that the addition of amine compounds had successfully reduced the formaldehyde emission up to 57% when 0.8% cyclopentylamine was added to urea formaldehyde (UF) resin. However, addition of formaldehyde scavenger into the UF resin might interfere its curing mechanism and consequently affect the properties of particleboard adversely (Puttasukkha et al. 2015). In addition, there is little or no information on the application of amine compounds as formaldehyde scavenger in the production of particleboard. Therefore, the objective of this study is to investigate the effects of propylamine in the reduction of formaldehyde emitted from UF-bonded particleboard as well as its physical and mechanical properties.

MATERIALS AND METHOD

Rubberwood particles for particleboard fabrication in this study were supplied by Hevea Board Berhad, a particleboard factory located at Gemas, Negeri Sembilan. The particles were dried in a laboratory oven to 3 % moisture content (MC) prior to particleboard production. E1 Urea formaldehyde (UF) resin with 65 % solid content was purchased from Aica chemical (M) Sdn. Bhd., Senawang, Selangor. Propylamine purchased from Evergreen Engineering

& Resources, Semenyih, Selangor was used as formaldehyde scavenger. During resin mixing, 1 % of propylamine and 1 % of ammonium sulphate as hardener based on resin solid weights were mixed with 8 %, 10 %, 12 %, 14 % and 16 % of UF resin. The UF resin dosages were based on the dry particles weight and denoted as UF8, UF10, UF12, UF14 and UF16, respectively. 0.5 % of wax based on dry particles weight was also incorporated into the resin mixtures. The mixtures of UF resin, formaldehyde scavenger, hardener and wax were sprayed onto the rubberwood particles while blending in a blender. A mat of 340 x 340 x 12 mm was formed from the resinated particles after blending. The formed mat was then subjected to hot pressing at 180°C for 270 seconds. A total of 12 boards, 2 boards for each resin dosage +1 set of control, with targeted density of 680 kg·m^{-3} were produced. The control particleboard was made from 8 % UF resin admixed with 1 % ammonium sulphate and 0.5 % of wax.

The produced particleboards were conditioned in a conditioning room at 20 ± 2°C and relative humidity (RH) of 65 ± 5 % until constant mass was reached. The conditioned boards were cut into required testing size according to JIS A 5908:2003 and JIS A 1460: 2001. Physical and mechanical properties of the particleboard such as water absorption (WA), thickness swelling (TS), modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding (IB) strength were tested according to JIS A 5908:2003. On the other hand, formaldehyde emission (FE) from the particleboard was analyzed based on the procedure stated in JIS A 1460:2001. Analysis of variance (ANOVA) was conducted to evaluate the effects of formaldehyde scavenger on the properties of the particleboards. The differences between the average values were separated using Tukey's Honest Significant Difference (HSD) test.

RESULTS AND DISCUSSION

Formaldehyde emission values of the control board and particleboard bonded with different dosages of propylamine-incorporated UF resin are tabulated in Fig. 1. From the figure, one can see that incorporation of propylamine has reduced the formaldehyde emission of the produced particleboard. Reduction ranged from 33 to 65 % was observed when 1 % of propylamine were added into the UF resin. Introduction of amines caused the density of aminomethylene bonds along the chain of the resins diminish and subsequently reduced the amount of emittance of formaldehyde (Ebewele et al. 1991). However, the formaldehyde emission level increased along with the increasing dosage of UF. When the UF resin dosage was increased from 8 to 16 %

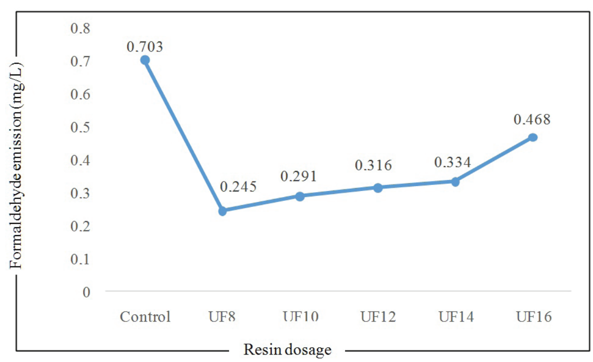

Fig. 1: Formaldehyde emission values of the particleboard made with different UF resin dosages.

(UF 8 to UF 16), an increase of 47.6 % in formaldehyde emission was observed, suggesting that higher dosage of formaldehyde scavenger is needed when higher resin dosage is used. All the particleboard made with propylamine-added UF resin achieved at least F*** (≤ 0.5 mg/L) emission level as stated in JIS standard compared to F** (≤ 1.5 mg/L) in control. The emission limit of the Japanese F*** class is approximately equivalent to European E0 class, while the F** emission limits are comparable to European E1 class (Athanassiadou and Ohlmeyer 2009).

In regard to properties of the particleboard, Tab. 1 summarized the average values of physical and mechanical properties of particleboard produced in this study.

Tab.1: Mechanical and physical properties of particleboard made with different UF resin dosages.

Type	Density ($kg \cdot m^{-3}$)	Water absorption (%)	Thickness swelling (%)	Modulus of rupture ($N \cdot mm^{-2}$)	Modulus of elasticity ($N \cdot mm^{-2}$)	Internal bonding ($N \cdot mm^{-2}$)
Control	685.3 ± 8.0^{a}	46.07 ± 1.48^{a}	28.01 ± 1.89^{ab}	14.38 ± 1.90^{a}	2354 ± 185^{a}	1.40 ± 0.31^{a}
UF8	663.4 ± 18.4^{a}	95.54 ± 7.75^{d}	37.35 ± 4.60^{c}	8.71 ± 0.89^{b}	1769 ± 174^{b}	0.29 ± 0.05^{b}
UF10	668.4 ± 34.9^{a}	84.02 ± 4.62^{c}	32.23 ± 2.82^{bc}	13.49 ± 3.30^{ab}	2151 ± 255^{ab}	0.52 ± 0.20^{b}
UF12	691.6 ± 16.8^{a}	80.32 ± 3.21^{c}	31.82 ± 2.45^{bc}	13.61 ± 1.73^{ab}	2355 ± 290^{a}	0.54 ± 0.23^{b}
UF14	687.4 ± 20.3^{a}	79.55 ± 3.22^{bc}	29.04 ± 3.66^{ab}	15.25 ± 4.30^{a}	2485 ± 557^{a}	0.56 ± 0.23^{b}
UF16	674.4 ± 50.5^{a}	71.35 ± 2.24^{b}	23.60 ± 2.31^{a}	16.44 ± 1.40^{a}	2702 ± 398^{a}	0.67 ± 0.21^{b}

The values after ± are standard deviations; means followed by the same letter in the same column are not significantly different at $P \leq 0.05$

When 1 % propylamine were incorporated into 8% UF resin (UF8), a drastically reduction in both physical and mechanical properties was observed in comparison to control. A reduction of 39.4 % was recorded in modulus of rupture (MOR) as it decreased from 14.38 to 8.71 $N \cdot mm^{-2}$. This value failed to meet the minimum requirement of 13.0 $N \cdot mm^{-2}$ stated in JIS standard. 24.9 % and 79.3 % reduction were also found in modulus of elasticity (MOE) and internal bonding (IB) strength, respectively. Apart from that, addition of propylamine also adversely affected the physical properties as the values of water absorption (WA) and thickness swelling (TS) showed an increment of 107.4 % and 33.3 %, respectively. Therefore, higher dosages of UF resin were used to counterbalance the loss of strength and dimensional stability. Based on the results, both physical and mechanical properties increased along with increasing dosage of UF resin. The finding was in agreement with Papadopoulos (2006) who revealed that the dimensional stability of UF-bonded particleboard was improved when higher dosage of resin was used. Improvement in MOR and IB were also reported in the same study. When the resin dosage increased to 10 % (UF), the MOR value met the minimum requirement of JIS standard. At the dosage level of 14 % (UF14), the properties of particleboard were found comparable to the control as no significant different was observed between UF14 and control. The maximum allowable thickness swelling of particleboard stated in JIS standard is 12 %, unfortunately, all the particleboard failed to complied with the standard. Higher dosage of wax can be added into the resin mixtures to enhance its thickness swelling in the future study.

CONCLUSIONS

This study examined the effectiveness of propylamine as a formaldehyde scavenger in particleboard production. The results showed that addition of 1 % propylamine has successfully reduced the formaldehyde emission level of particleboard from F** to F*** and even F**** (≤ 0.3) for UF10. However, when taking physical and mechanical properties into consideration, particleboard made with 14 % UF resin (UF14) exhibited the most ideal properties with relatively lower formaldehyde emission but comparable physical and mechanical properties to that of the control particleboard.

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