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Research Paper

Study on Dimensional Stability of Particleboard Made Using Glutardialdehyde Modified Corn Starch as the Binder at Various Relative Humidity

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Abstract

The objective of the study was to evaluate the dimensional stability of experimental particleboard panels made from rubberwood (*Hevea brasiliensis*) using modified starch as binder. Panels were manufactured using 15% corn starch modified with glutardialdehyde and 13% modified starch with 2% Urea Formaldehyde resin as improvement. The particleboards were tested for their dimensional stability towards moisture. Results found that the 2% replacement of modified starch with urea formaldehyde resin showed a little increased in dimensional stability compared to using glutardialdehyde modified corn starch only as the binder. Therefore, this study indicated that combination of modified corn starch and urea formaldehyde resin can have a potential to be used as an improved binder to produce particleboard panels with accepted properties.

Keywords: *Composite; Humidity; Particleboard; Starch; Wood*

1. Introduction

Particleboard and other wood based composites are among the excellent choice of end product to be made using woody material wastes. These waste might come from sawmilling process, leftovers of logging activity, broken wooden furniture, agriculture waste and municipal waste [1]. Particleboard manufacturing will ensure the woody materials are not wasted and left to decay only besides it can help to reduce the problem of waste disposal.

However, woody material is susceptible to moisture attack. Wood based panels especially the particleboards will swell and deteriorate after certain amount of water absorption [2]. Using water resistance polymer as the binder or matrix in wood based panels will help to reduce water uptake by the composites. Formaldehyde resins are among the commonly used binder in particleboard making [3]. However, the carcinogenicity of the fume released from the manufactured panels draw concern by the society on their health. Thus, reduction of the formaldehyde based adhesives is needed by replacing it with other formaldehyde free adhesives. One of the alternative is starch based adhesive [4]. However, starch have high affinity towards moisture. Modification of the starch is needed to reduce their water absorption property. Therefore, this study investigates the dimensional stability of particleboard made using glutardialdehyde modified corn starch as the binder, with and without the help of small amount of urea formaldehyde resin, after exposure to different relative humidity environment levels.

2. Materials and methods

2.1 Sample preparation

Commercially produced rubberwood (Hevea brasiliensis) particles supplied by a local particleboard company in Negeri Sembilan, Malaysia were used to make experimental panels. Obtained wood particles were dried to 2% moisture content in a laboratory type oven. Corn starch in powder form modified with glutaraldehyde in liquid form in a ratio of 1:2 (w/w) was used as binder in a ratio of 15% based oven dry particle weight. Commercial Urea formaldehyde resin was obtained from Hexion Specialty Chemical Company based in Penang, Malaysia.

Corn starch powder was dissolved in distilled water with a room temperature. Mixture was stirred and temperature was increased slowly before 25% glutardialdehyde solution was added at temperature 60 ˚C. Mixture was stirred continuously until resinification was attained [5, 6].

A total of 60 panels, five for each density level with dimension of 20.1 cm by 20. 1 cm by 0.5 cm was manufactured for the experiments [7]. Panels were made for target density levels of 0.60 g/cm3, 0.70 g/cm3 and 0.80 g/cm3. Fifteen percent modified corn starch was manually mixed with rubberwood particles before they were processed in a computer control press using a pressure of 5 MPa at a temperature of 165˚C for 20 min. Panels were conditioned in a climate chamber with a temperature of 20˚C and a relative humidity of 65% for 2 weeks [8].

After the samples were conditioned, their dimensional stability towards moisture were determined. Thickness swelling and water absorbtion of particleboard after exposure to different relative humidity level were evaluated based on Japanese Industrial Standard. The test pieces of 30 mm × 30 mm were cut from particleboards and conditioned at 25 °C and 50 % relative humidity for 24 hours. The width, length and thickness of the sample were measured, weighed and later incubated in relative humidity chamber at 35 %, 55 %, 75 % and 95 % relative humidity. After 24 hours, the test pieces were taken and the dimensions after water immersion were measured. Test pieces were weighed to determined the amount of water absorbed. Samples were placed back into the humidity chamber for 24 hours. Test pieces dimensions were taken and reweighed. Procedure was repeated until the dimensions of the test piece and their weight remain constant. Thickness swelling and water absorbtion capacity were calculated using the following equation;

$$Swelling\ or\ Water\ absorbtion, \% = \frac{m_i - m_0}{m_0} \times 100$$

Where m0 is measurement before exposure and mi is measurement after exposure.

3. Results and discussion

3.1 Thickness swelling after exposed to different relative humidity

Figure 1, Figure 2, Figure 3 and Figure 4 showed the thickness swelling of manufactured particleboards at 35 %, 55 %, 75 % and 95 % relative humidity, respectively. Thickness swelling at relative humidity of 35 % showed shrinkage in sample's thickness. Generally, thickness swelling of the samples increased as the density of the panel were increased, due to the springback force [9, 10]. Thickness swelling of particleboards in different relative humidity depends on open surface of the samples which allows penetration of moisture [11]. Table 1 showed the statistical analysis of variance, compared between different densities within the same binder type. The results showed that thickness swelling were significantly different when compared between different densities for almost all type of binders. This showed that density played important role in influencing the thickness swelling of the particleboards.

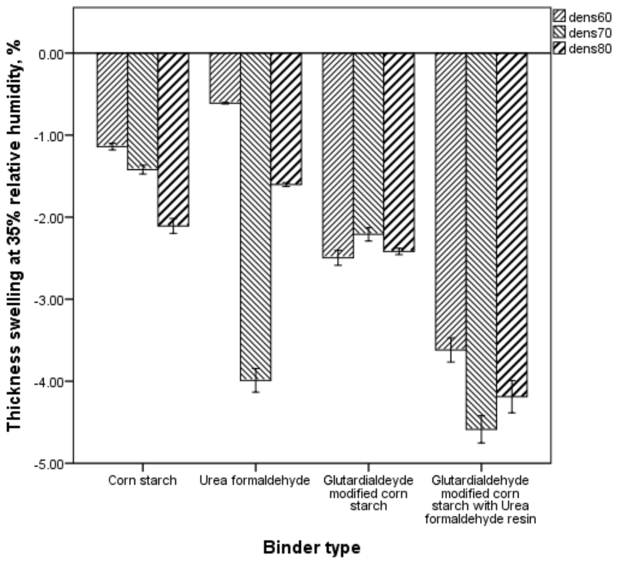

Figure 1: Thickness swelling of produced particleboards at 35% relative humidity. *Dens60 = 0.60 g/cm3 density, dens70 = 0.70 g/cm3 density and dens80 = 0.80 g/cm3 density.

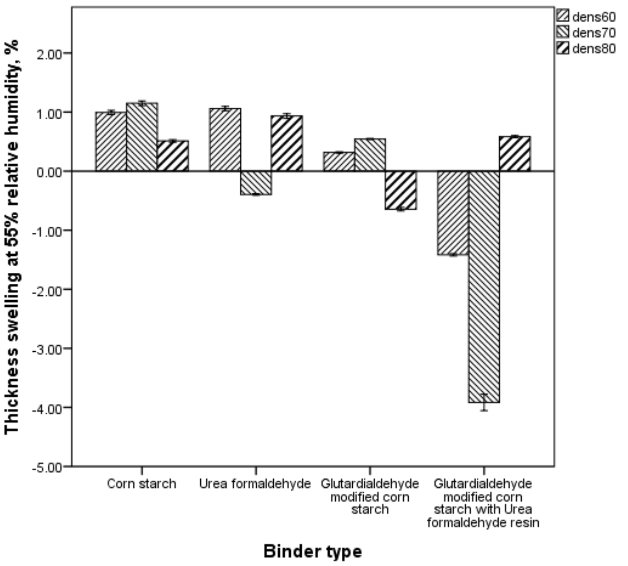

Figure 2: Thickness swelling of produced particleboards at 55% relative humidity. *Dens60 = 0.60 g/cm3 density, dens70 = 0.70 g/cm3 density and dens80 = 0.80 g/cm3 density.

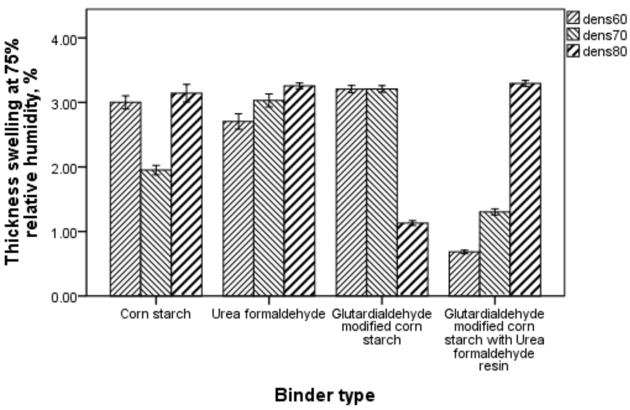

Figure 3: Thickness swelling of produced particleboards at 75% relative humidity. *Dens60 = 0.60 g/cm3 density, dens70 = 0.70 g/cm3 density and dens80 = 0.80 g/cm3 density.

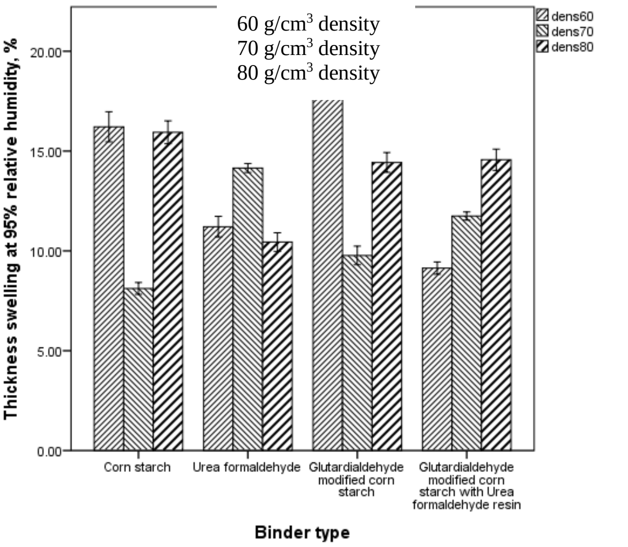

Figure 4: Thickness swelling of produced particleboards at 95% relative humidity. *Dens60 = 0.60 g/cm3 density, dens70 = 0.70 g/cm3 density and dens80 = 0.80 g/cm3 density.

Particleboard made using glutardialdehyde modified corn starch with 2 % urea formaldehyde resin showed extreme thickness shrinkage at 55 % relative humidity. This could be due the sample had more moisture, thus more shrinkage was happening when placed in low humidity environment [12]. There were no pattern of increasing or decreasing showed by particleboard made using native starch as the binder and modified starch as the binder. Some particleboard made using modified starch as the binder shrink more than the particleboard made using native starch as the binder while the others showed the other way. Difference in binder type did not affect much in the thickness swelling compared to difference in density.

Table 1: Statistical analysis of thickness swelling of particleboards made using different binder after exposure to different relative humidity, compared between different densities

Panel type**	Target density (g/cm^3)	Thickness swelling at relative humidity			
		35%	55%	75%	95%
CS	0.60	-1.14 (0.05)a	0.99 (0.05)a	3.00 (0.13)a	16.22 (0.98)a
	0.70	-1.42 (0.07)b	1.15 (0.05)b	1.95 (0.09)b	8.12 (0.39)b
	0.80	-2.11 (0.12)c	0.51 (0.03)c	3.14 (0.18)a	15.94 (0.74)a
UF	0.60	-1.11 (0.05)a	1.60 (0.09)a	1.06 (0.06)a	9.70 (0.56)a
	0.70	-2.27 (0.09)b	1.22 (0.05)b	2.03 (0.08)b	10.75 (0.21)b
	0.80	-2.80 (0.11)c	1.71 (0.06)c	1.94 (0.07)c	11.54 (0.54)c
GMCS	0.60	-3.85 (0.19)a	-0.89 (0.02)a	2.19 (0.11)a	6.21 (0.14)a
	0.70	-2.83 (0.17)b	0.59 (0.03)b	2.35 (0.16)b	9.49 (0.44)b
	0.80	-4.85 (0.10)c	-1.53 (0.03)c	1.97 (0.04)c	7.99 (0.51)c
GMCS2 UF	0.60	-0.61 (0.01)a	1.06 (0.05)a	2.70 (0.16)a	11.21 (0.67)a
	0.70	-3.99 (0.19)b	-0.39 (0.02)b	3.03 (0.13)b	14.15 (0.29)b
	0.80	-1.60 (0.03)c	0.93 (0.05)c	3.25 (0.06)c	10.44 (0.61)c

*different letter in a same column and same type of binder shows significant difference at α value of 0.05

**CS = Corn starch; UF = Urea Formaldehyde; GMCS = Glutardialdehyde modified corn starch; GMCS2UF = Glutardialdehyde modified corn starch with 2% urea formaldehyde.

3.2 Water absorption after exposed to different relative humidity

Figure 5, Figure 6, Figure 7 and Figure 8 showed the water absorption of manufactured particleboards at 35 %, 55 %, 75 % and 95 % relative humidity, respectively. Particleboard samples expels water at 35 % relative humidity. Low surrounding humidity forced the samples to balance their moisture content by releasing water from the sample. As a result, all of the particleboard samples showed negative values of water absorption where initial sample weight were higher than the final weight.

At 55 % of relative humidity, 10 out of 12 sample types still showed negative values for water absorption. Further increment of relative humidity showed higher water absorption, recorded between 2.30 % and 2.88 % at 75 % of relative humidity. A minimum value of 6.30 % was found for water absorption at 95 % relative humidity while the maximum was recorded at 8.75 %. Higher relative humidity increased the water absorption values for particleboard samples. However, there were no trend had been observed between particleboards made using native starch as the binder and particleboards made using modified starch as the binder.

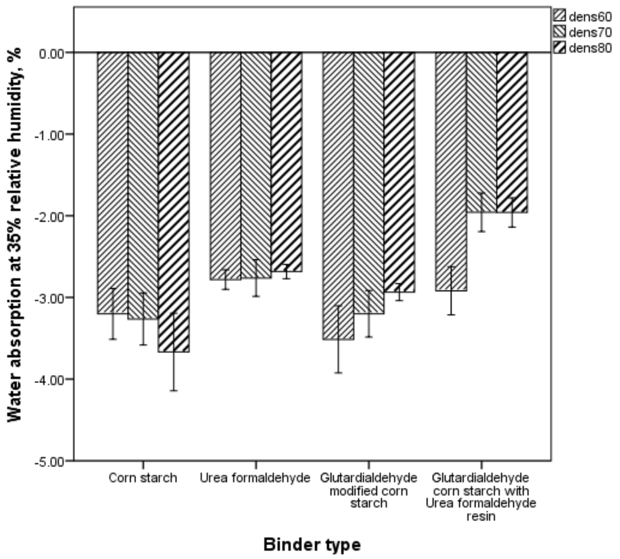

Table 5: Water absorption at 35% relative humidity. *Dens60 = 0.60 g/cm3 density, dens70 = 0.70 g/cm3 density and dens80 = 0.80 g/cm3 density.

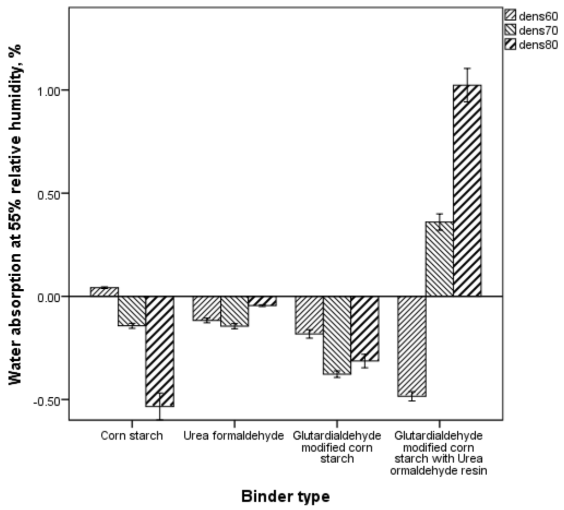

Figure 6: Water absorption at 55% relative humidity. *Dens60 = 0.60 g/cm3 density, dens70 = 0.70 g/cm3 density and dens80 = 0.80 g/cm3 density.

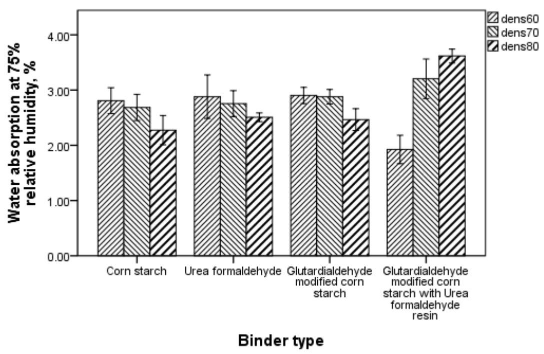

Figure 7: Water absorption at 75% relative humidity. *Dens60 = 0.60 g/cm3 density, dens70 = 0.70 g/cm3 density and dens80 = 0.80 g/cm3 density.

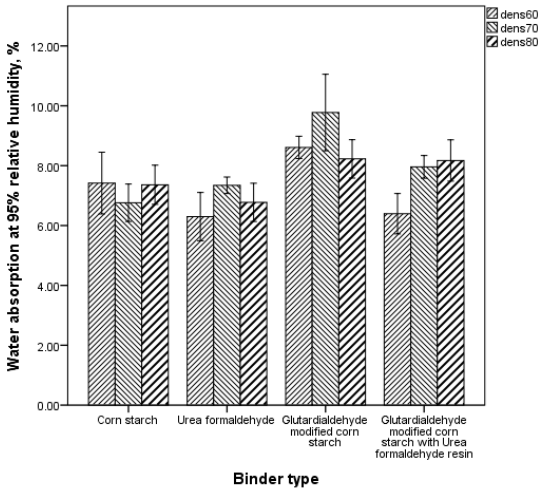

Figure 8: Water absorption at 95% relative humidity. *Dens60 = 0.60 g/cm3 density, dens70 = 0.70 g/cm3 density and dens80 = 0.80 g/cm3 density.

Statistical analysis of water absorption of after exposure to different relative humidity, compared between different densities also showed less samples with significant difference when compared to each other as shown in Table 2. This showed that water absorption was not affected by different density but affected by open surface and pores of the samples.

Table 2: Statistical analysis of water absorption of after exposure to different relative humidity, compared between different densities

Panel type**	Target density (g/cm^3)	Water absorption at relative humidity			
		35%	55%	75%	95%
CS	0.60	-3.20 (0.40)a	0.04 (0.01)a	2.81 (0.30)a	7.42 (1.34)a
	0.70	-3.26 (0.41)a	-0.14 (0.02)b	2.68 (0.31)a	6.76 (0.81)a
	0.80	-3.67 (0.62)a	-0.53 (0.08)c	2.27 (0.34)b	7.36 (0.85)a
UF	0.60	-2.90 (0.37)a	-0.07 (0.01)a	2.71 (0.43)a	6.82 (1.07)a
	0.70	-2.78 (0.27)a	-0.09 (0.01)a	2.64 (0.28)a	8.25 (0.38)b
	0.80	-2.83 (0.26)a	-0.23 (0.02)b	2.49 (0.24)a	8.75 (1.07)b
GMCS	0.60	-3.02 (0.46)a	-0.94 (0.05)a	2.30 (0.25)a	6.53 (0.40)a
	0.70	-2.82 (0.43)ab	-0.27 (0.03)b	2.36 (0.37)a	8.09 (1.08)b
	0.80	-2.43 (0.09)b	0.07 (0.01)c	2.41 (0.08)a	6.75 (0.74)a
GMCS2 UF	0.60	-2.78 (0.15)a	-0.12 (0.01)a	2.88 (0.51)a	6.30 (1.05)a
	0.70	-2.76 (0.29)a	-0.14 (0.02)b	2.75 (0.31)a	7.34 (0.36)b
	0.80	-2.68 (0.11)a	-0.04 (0.01)c	2.51 (0.10)a	6.77 (0.83)ab

*different letter in a same column and same type of binder shows significant difference at α value of 0.05
**CS = Corn starch; UF = Urea Formaldehyde; GMCS = Glutardialdehyde modified corn starch; GMCS2UF = Glutardialdehyde modified corn starch with 2% urea formaldehyde.

4. Conclusion

Thickness swelling and water absorption of the manufactured particleboards were more dependent on the density of the wood panels rather than the type of binder. Higher relative humidity leads to lesser dimensional stability where the water vapour were being absorbed through pores into the wood panels and break the bonds inside.

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