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Research Paper

Fungal Resistance of Particleboard Made Using Glutardialdehyde Modified Corn Starch as the Binder with the Aid of Urea Formaldehyde Resin

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Abstract

Particleboard is a popular wood composite made using mixtures of wood particles and resin, binder or adhesives, pressed at high temperature to cured. Despite its popularity, formaldehyde-based adhesives used in the formulations lead to cancerous effect as the formaldehyde fumes released from the unreacted chemicals travel into human lungs. Therefore this study tries to reduce the utilization of formaldehyde-based resin by replacement of a significant portion of the binder with glutardialdehyde modified corn starch as the binder. However, this practice could lower the durability of the particleboards against biological attack. Therefore, this study evaluates the fungal resistance of the particleboard panels. Panels were manufactured using 83:15:2 ratio of wood, corn starch-modified with glutardialdehyde and formaldehyde resin, respectively, as an improvement. Four types of wood-degrading fungal were chosen including *Trametes versicolor*, *Formitopsis palustris*, *Schizophyllum commune* and *Pycnoporus sangineus*. Some of the particleboard showed a little increased in fungal resistance when 2% urea formaldehyde was added, compared to using glutardialdehyde modified corn starch and starch only as the binder. Nine out of twelve samples showed a decrement in fungal degradation by using glutardialdehyde modified starch as the binder. Meanwhile, 6 out of 12 samples showed higher fungal resistance after additional of 2% urea formaldehyde in the binder formulation. Based on the results, combination of modified corn starch and urea formaldehyde resin could have a potential to be used in particleboard making without reducing the initial resistance towards fungal attack.

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

1. Introduction

The manufacturing of reconstituted wood products such as particleboard is essential to enable the utilization of low-grade timbers of fast-growing species or small diameter logs obtained from thinning operations [1]. Biological degradation of wood is a common thing in natural, unmodified woody materials. Some of the degradation agents are termites, wood boring beetles, fungal and bacteria. Reconstituted wood panels are so susceptible to fungal attack as reported by Chung, Wi [2] fiberboard attacked by several mold fungi were losing about 12%-18% of its weight, with strength reduction of about 50%.

The mold fungi consumed mainly hemicellulose and a-cellulose, whereas lignin was usually left unattacked. In reducing the degradation action of these organisms, several techniques had been developed, primarily by the addition of chemicals which can stop or slow down the growth of fungal. Terzi, Köse [3] had a different approach by mixing waste tire rubber to reduce biological decay of particleboard. However, the fungal still have some effect on the degradation of the produced panels [4]. Usually, incorporation of chemicals is done. Therefore, this work is done to study the effect of urea formaldehyde resin addition to particleboards made using Glutardialdehyde modified starch as the binder.

2. Materials and methods

2.1 Sample preparation

Rubberwood (Hevea brasiliensis) trunks were obtained from local rubber tree plantation in Negeri Sembilan, Malaysia. Tree trunks were cut into smaller pieces before chipped and ground. Wood particles were dried to 2% moisture content before used. Powder form corn starch was obtained from Sigma Aldrich. Binder preparation was done by diluting corn starch in water, heated up to 90 ^{o}C with the addition of glutardialdehyde, 25% concentration in a ratio of 1:2 (w/w), glutardialdehyde: corn starch. Commercial Urea formaldehyde resin was obtained from Momento Chemical Company located in Seberang Prai, Penang, Malaysia while glutardialdehyde was obtained from Sigma Aldrich. The mixture was homogenized until resinification was attained [5].

Three target density levels were chosen for particleboard making which were 0.60 gcm-3, 0.70 gcm-3 and 0.80 gcm-3. Five replicates were made for each density level. Mold of 20.1 cm x 20. 1 cm x 0.5

cm was used to form panels [6]. Wood particles were mixed with 15% modified corn starch with additional 2% of urea formaldehyde resin. The mixture was placed into stainless steel mold before pre-pressed to form a mat. Layered mat was slowly pressed into a computer control press using a pressure of 5 Mpa at a temperature of 165˚C for 20 min to allow air and moisture release. Manufactured panels were conditioned in a controlled room at a temperature of 20˚C and a relative humidity of 65% for two weeks before ready to be tested [7, 8].

2.2 Resistance to fungal attack

Determination of particleboard resistance against fungal attack was done according to Kamdem et al. [9] with modification of exposure length. Test pieces from particleboards were cut by the dimension of 25±0.5 mm × 25±0.1 mm × 5±0.1 mm. Test pieces were conditioned in an electronically controlled conditioning chamber at 25 °C and 65 % relative humidity before testing. Samples were oven dried to determine their moisture content. The water holding capacity (WHC) of the soil were also determined to ensure adequate moisture was available in the soil.

A 400 ml volume glass bottle was filled with 95 g of soil substrate, obtained from Tesco supermarket, Penang, Malaysia. Water holding capacity was 40% and a pH of 6.5. Debris and contaminants were removed from the soil and sieved through a US No. 6 sieve (6 mesh, 3.35 mm) and stored in plastic bags. The mouth of the bottles was covered with a plastic net to ensure aeration. The wood decay fungi used were including Trametes versicolor, Formitopsis palustris, Schizophyllum commune and Pycnoporus sangineus.

The soil was inserted into each bottle, and the bottles were autoclaved for one h at 121 °C. Conditioned samples were weighed for initial mass, put inside the bottle with autoclaved soil and autoclaved again at 103 °C for 20 min. An actively growing colony of the chosen test fungus was taken, and an agar plug was cut to get a fresh and healthy sample. One agar plug was inoculated onto each sample. Three sterilized specimens from each board type were used for each decay fungus. All specimens were placed in an incubator with 25 °C temperature and 85% relative humidity. After 6 months, specimens were carefully taken out of the bottles before brushing off the mycelium from the surfaces with a soft sponge, and the specimens were placed on a tray [10]. Samples were dried in an oven at 40 °C for 3 hrs to reduce the moisture content to at least 30%. Samples were then conditioned in the conditioning room set at 20 °C and 70% relative humidity for 21 days [11]. The degree of fungal attack was estimated by comparing the weight loss after 6 months exposure to fungus in ratio to its initial weight, estimated using the equation;

$$Degree\ of\ fungal\ attack, \% = \frac{m_i - m_f}{m_i} \times 100$$

Where mi is the initial weight of the conditioned specimens before fungal exposure and mf are the final weight of conditioned specimens after fungal exposure.

3. Results and discussion

Figure 1 showed the percentage of degradation of manufactured particleboards after exposure to Formitopsis palustris fungi. The results are not showing a good pattern of degradation whether by using modified starch as the binder or increasing their density level. Among all particleboards made using modified starch as the binder, particleboard made using urea-formaldehyde as the binder recorded the lowest weight loss at all density levels.

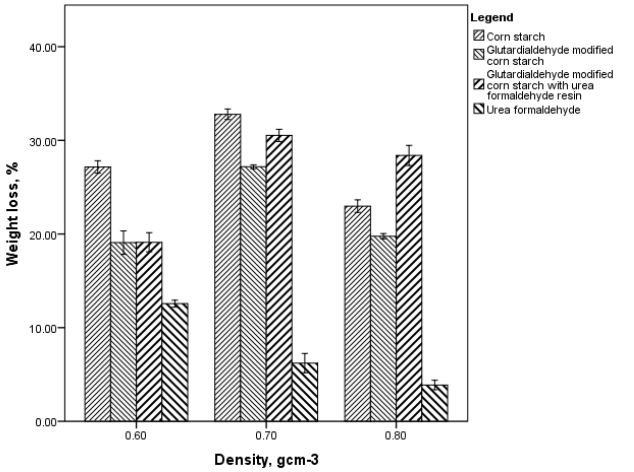

Figure 1 Weight loss of particleboard after exposure to *Formitopsis palustris* fungal.

The percentage of degradation of manufactured particleboards after exposure to Pycnoporus sanguineus fungi were shown in Figure 2. From the results, there was no relationship shown between degradation and density increment. All of the samples showed fluctuations in results, as low as 8.63 % of degradation, obtained by particleboard made using urea formaldehyde resin at 0.70 g/cm3 up to 34.43 % degradation, obtained by particleboard made using corn starch as the binder at 0.70 g/cm3 density level. Statistical analysis in the Table 1 showed many samples were significantly different when compared to different density level despite no trend of decreasing or increasing were shown.

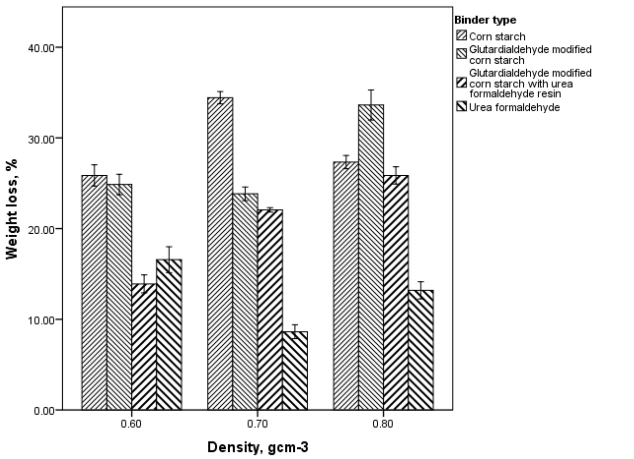

Figure 2 Weight loss of particleboard after exposure to *Pycnoporus sanguineus* fungal.

Figure 3 showed the percentage of degradation of manufactured particleboards after exposure to *Schizophyllum commune* fungi. There was no pattern showed by the results, except for particleboard made at 0.80 g/cm^3 density. The weight loss in descending order are started with particleboard made using corn starch followed by particleboard made using Glutardialdehyde modified corn starch, particleboard made using Glutardialdehyde modified corn starch with 2% urea formaldehyde resin, and particleboard made using urea formaldehyde, finally. Table 1 also showed the statistical analysis for *Schizophyllum commune* fungal degradation test of manufactured particleboards, compared between different densities. No significant difference was shown when compared to different densities.

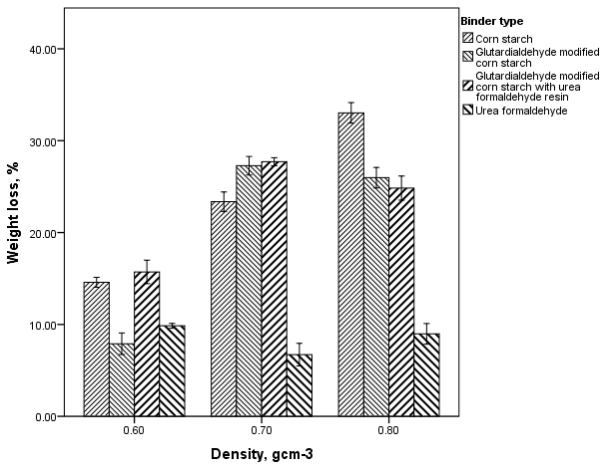

Figure 3 Weight loss of particleboard after exposure to *Schizophyllum commune* fungal.

Figure 4 showed the percentage of degradation of manufactured particleboards after 24 weeks exposed to *Trametes versicolor* fungi. The increment of density did not affect the amount of deterioration by the fungal towards the particleboards. Statistical analysis for fungal degradation test of manufactured particleboards, compared to different density were tabulated in Table 1, showing most samples were not significantly different to each other when compared to different density. However, binder type showed some trend where using modified starch as the binder decreased the degradation of particleboard, except at 0.80 g/cm^3 density level. Additional 2 % urea formaldehyde also helped to reduce the amount of degradation caused by *Trametes versicolor* fungi drastically for particleboard at 0.60 g/cm^3 and 0.80 g/cm^3 density levels.

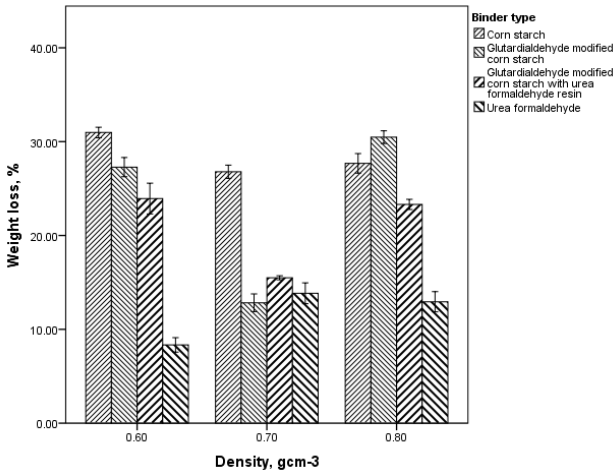

Figure 4 Weight loss of particleboard after exposure to *Trametes versicolor* fungal.

Table 1 Statistical analysis for fungal degradation test of manufactured particleboards, compared to the different density

Panel type**	Target density (g/cm^3)	Fungal exposure test, decay (%)*			
		SC	PS	FP	TV
CS	0.60	14.59 (0.71)a	25.86 (1.52)a	27.16 (0.87)a	30.97 (0.74)a
	0.70	23.36 (1.39)b	34.43 (0.88)b	32.78 (0.74)b	26.79 (0.92)b
	0.80	33.03 (1.46)c	27.34 (0.95)c	22.98 (0.88)c	27.69 (1.35)b
UF	0.60	9.86 (0.34)a	16.57 (1.85)a	12.57 (0.48)a	8.34 (1.01)a
	0.70	6.72 (1.60)b	8.63 (1.00)b	6.21 (1.34)b	13.84 (1.45)b
	0.80	8.98 (1.46)a	13.19 (1.24)c	3.88 (0.66)c	12.94 (1.39)b
GMCS	0.60	7.90 (1.53)a	24.86 (1.47)a	19.08 (1.63)a	27.29 (1.33)a
	0.70	27.28 (1.31)b	23.84 (0.98) a	27.18 (0.27)b	12.83 (1.23)b
	0.80	25.98 (1.45)b	33.63 (2.16)b	19.77 (0.36)a	30.48 (0.88)c
GMCS2 UF	0.60	15.72 (1.66)a	13.90 (1.29)a	19.11 (1.33)a	23.94 (2.14)a
	0.70	27.71 (0.57)b	22.06 (0.32)b	30.53 (0.86)b	15.49 (0.28)b
	0.80	24.85 (1.71)c	25.86 (1.24)c	28.39 (1.40)c	23.31 (0.71)a

*SC = *Schizophyllum commune;* PS = *Pycnoporus sanguineus;* FP= *Formitopsis palustris;* TV = *Trametes versicolor.*
**CS = Corn starch; UF = Urea Formaldehyde; GMCS = Glutardialdehyde modified corn starch; GMCS2UF = Glutardialdehyde modified corn starch with 2% urea formaldehyde.

4. Conclusion

From the results obtained, it was found that the 2% replacement of modified starch with urea formaldehyde resin made some of the particleboard showed a little increased in fungal resistance compared to using glutardialdehyde modified corn starch and starch only as the binder [12]. Nine out of 12 samples showed a decrement in fungal degradation when using glutardialdehyde modified starch as the binder. Additional of 2% urea formaldehyde in the binder formulation showed higher fungal resistance for 6 out of 12 samples. Last but not least, using solely 15% urea-formaldehyde as the binder showed fungal attack reduction for 9 out of 12 samples. Considering all the results analyzed, this study indicated that combination of modified corn starch and urea formaldehyde resin have the potential to be used in particleboard making without drastically reducing the initial resistance towards fungal attack.
In this section, you should present the conclusion of the paper. Conclusions must focus on the novelty and exceptional results you acquired. Allow a sufficient space in the article for conclusions. Do not repeat the contents of Introduction or the Abstract. Focus on the essential things of your article.

Acknowledgment

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