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Effect of Dricon® in Kenaf Core Particleboard Towards On Fire Performance

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Abstract

One layer kenaf core particleboard was treated with one of the advanced fire retardants, Dricon® . The percentage of 8 % (w/w) and 12 % (w/w) of Dricon® were incorporated into three different board densities (350 kg/m3, 450 kg/m3 and 550 kg/m3) which were fabricated with three resin loadings (w/w) of urea formaldehyde (8%, 10% and 12%). Each of treated and untreated particleboard has been tested with blow torch and fire propagation tests. The fire propagation test was evaluated by using performance index (I), which indicates the level of heat release of the tested boards. Blow torch test resulted the decreasing of sample's weight loss of the Dricon®'s sample than the control samples. Fire propagation test indicated lower value of performances index or lower heat release of the treated samples compared with the untreated ones.

Keywords: kenaf; Dricon®; blow torch; fire propagation; weight loss

1. INTRODUCTION

Kenaf is a warm season annual fiber crop closely related to cotton (Gossypium hirsutum L., Malvaceae) and okra (Abelmoschus esculentus L., Malvaceae) [1]. The advantages of kenaf are that its components can be commercialized including the bark, bast, core fiber, and the leaves. The diverse new uses for kenaf include its utilization in paper products, building materials, absorbents, textiles, and livestock feed [2]. It's also possible to compress the core in board [3]. Due to dwindling of material supplied especially from rubberwood to the wood-based panel industry in Malaysia, kenaf would become a good alternative material in such industry for the coming years because of it is fast growing (almost 6 months) and is feasible to cultivate in Malaysia which is a tropical country [4].

Particleboard is one of the most popular composite panel and it has been used widely in building industry. One of the important properties of the wood-based panel is fire performance that can be improved through by fire retardant treatment. Dricon® one of commercial fire retardant chemicals was used in this study. It has been produced by Hicksons Corporation and Dricon® is their registered trademark for the product. Dricon® is a composition of 27-33 % Boric Acid, 67-73 % Guanylurea Phosphate and 0.0-4.2 % Phosphoric Acid [5]. The Dricon® formulation was developed with high molecular weight, very limited solubility, and stability in higher temperature environments [6]. The advantages that Dricon® have, obviously better than 'old' fire retardants such as ammonium sulphate, ammonium phosphate and zinc chloride where it came with a combination of phosphoric acid and boric acid, which can act as fire retardant as well as a wood preserver.

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Fire performance of the composite panel can be evaluated through fire propagation performance index which indicates the amount of heat released from small panels of lining material within a compartment [8, 7]. The heat generated from chemical reactions during combustion process [7]. Fire propagation behavior of materials is divided into 3 categories;

(1) In decelerating or non-propagating behavior, the rate of fire propagation decreases with time or the heat not broadly spread and limited to the ignition zone only.

(2) In non accelerating behavior, fire propagates beyond the ignition zone although slowly.

(3) In accelerating behavior where fire propagates beyond the ignition zone very rapidly [7].

The use of urea formaldehyde resins as a major adhesive by the forest products is due to many advantages it has. The advantages that this conventional resin possesses are low cost, ease of use under a wide variety of curing conditions, low cure temperature, water solubility, and resistance to microorganisms and to abrasion, hardness, and excellent thermal properties [9]. The application of urea formaldehyde as an adhesive in the manufacturing of board have been used broadly by several researcher in their research [4, 5, 9, 12 and 15]. The objective of this study was to evaluate the fire properties kenaf core particleboard treated with Dricon®.

2. MATERIALS AND METHODS

2.1 Materials

Four-month old Kenaf of G-4 species was harvested from the MARDI trial plot in Serdang Selangor. Kenaf cores were obtained by removing the outer fibres from the stalks manually. The kenaf cores then were transformed to chips using a drum chipper machine, model Pallman PZ 8 before they were further refined with knife ring flaker machine model Pallmann PHT 120/430 in order to obtain 3-5 mm particles sizes. The particles were dried in an oven at 106 ^{0}C to achieve 5% MC. Urea formaldehyde (UF) resin at 64% solid content which was obtained from Dynea (M) Sdn. Bhd., Senawang, Negeri Sembilan was selected as a binder. Dricon® in a powder form was taken from Fire Protection Laboratory of Forest Research Institute Malaysia (FRIM), Kepong Selangor.

2.2 Methods

2.1 Sample Preparation

The mixing process between kenaf core particles and resin was done in a blender machine type of Dries Mixer. Three percentages of UF resin loadings used were 8%, 10% and 12% (based on air dry basis weight of fiber). The fire retardant agent called Dricon® (powder form) was blended evenly with the resinated kenaf particles at 8% and 12% (w/w) in the blender. The furnish was scattered in a wood deckle with dimensions of 340 × 340 × 12 mm^3 (length × width × thickness) to form a mat. The mat was pre-pressed in the cold press at 35 kg/cm^2 pressure and subsequently pressed in the hot press machine model Taihei at 170 ^{0}C to the targeted thickness of 12 mm for 6 minutes. The boards were produced with three different targeted densities, i.e. 350 kg/m^3, 450 kg/m^3 and 550 kg/m^3. The fabricated boards then were utilized for the blow torch and fire propagation test. Sample size for blow torch and fire propagation test samples were 225mm × 225 × 12 mm^3 (length × width × thickness). The description of the fabricated boards is as described in Table 1.

All samples prior to testing were kept in a conditioning chamber with 65% humidity at temperature of 20^0C for approximately 3 days.

Table 1: Description of the fabricated particleboard

Raw Material	Kenaf core particle (3-5 mm size)
Targeted board density	350 kg/m^3, 450 kg/$m^3$and 550 kg/m^3
Targeted board MC	12%
Board Size	(350 x 350 x 12) mm^3
Adhesive	
1.UF resin	8 %, 10 % and 12 %(w/w of oven dry kenaf particle)
2. Hardener (NH_4CL	3 % (based on UF)
Fire Retardants	
Dricon®, Mixture of :	8% and 10% (w/w of oven dry kenaf particle)
i) Guanylurea phosphate	
ii) Phosphoric Acid	
iii) Boric Acid	

2.2.2 Fire Propagation Test

The fire propagation test has been conducted in Standard and Industrial Research Institute of Malaysia (SIRIM). The conditioned samples with the sizes of 225 × 225 × 12 mm were subjected to fire propagation test based on British Standard BS 476: part 6, 1989 [10] using the apparatus shown in Diagram 1. The moisture content of tested particleboards was maintained at 12% prior to testing. The particleboard was tested with the face side exposed to the specified heating condition of the fire test. One particleboard samples were tested for each series. Firstly the samples were heated with butane ($CH_3CH_2CH_2CH_3$) gas for 165 sec and then heated by electrically heated nichrome heating elements to achieve 20 min exposure time. The increase in exhaust temperature given by the burning samples for 20 min was recorded at the following interval from the start: at ½ min intervals, up to 3 min, at 1 min intervals from 5 to 10 min and at 2 min intervals from 12 to 20 min. The I value is ranging from 0 to 100 in an increasing order of hazard. The calculation of the performance index was automatically performed by software which was readily installed in the computer at the Fire Protection Section, SIRIM QAS International Sdn. Bhd. The I values can also assist in evaluating flame spread of a material. The flame spread of a material refers to the ability of a material to support the spread of the flame across the surface. The performance was rated by propagation index, I, where the value of I less than 12 considered class 0. I value of 10-25 can be considered class 1 (very low flame spread) rating, class 2 (I value; 25-40), class 3 (I value; 40-55) and class 4 (I value; more than 55) [10]. The lower the index the better the resistance of a material for fire propagates. The index of performance, I, was calculated using Equation 1 as;

$$I = i1 + i2 + i3 \quad (1)$$

Where I = Propagation index (index of performance)

$$i1 = \sum_{1/2}^{3} \frac{Qm-Qc}{10t}$$

$$i2 = \sum_{5}^{10} \frac{Qm-Qc}{10t}$$

$$i3 = \sum_{12}^{20} \frac{Qm-Qc}{10t}$$

Qm = temperature rise recorded for specimen at time t
Qc = temperature rise recorded for calibration board at time t
and t = time in minutes from beginning of test.

Diagram 1 A fire-propagation apparatus at SIRIM

2.2.3 Blow Torch Test

The in-house method, blow torch testing (Diagram 2) was conducted at Fire Laboratory FRIM Kepong. All the samples before testing were conditioned in conditioning room at 65% humidity and 20^{0}C. The samples with the size of 225 × 225 mm were inclined at 45^{0} and the distance between the flame and the sample was set at 5 cm. The test time was set for 5 minutes and all the tests conducted in a draft-free room. One sample was tested at a time. The weights of all samples before and after exposed to the fire source were recorded. The percentage of weight loss of samples calculated following the Equation 2 as;

$$\text{Weight loss (\%)} = \frac{W1 - W2}{W1} \times 100\% \qquad (2)$$

Where; W1 = Weight of sample before blow torch test
W2 = Weight of sample after blow torch test

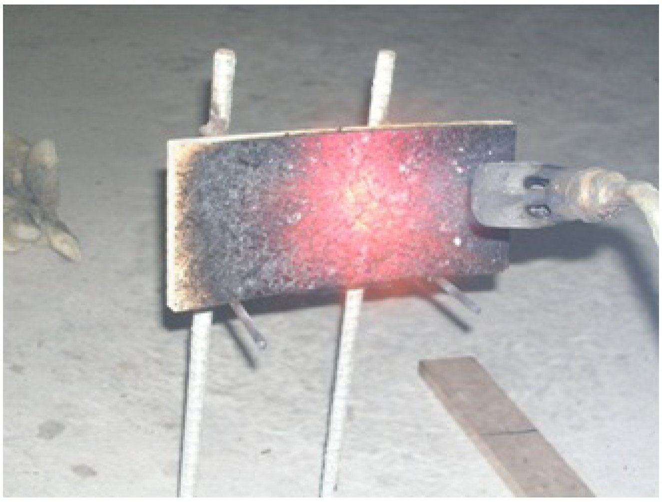

Diagram 2 A blow torch test is conducted in FRIM

3. RESULT AND DISCUSSION

3.1 Blow Torch Test

Table 2 shows the results of blow torch test using kenaf particleboard at various board densities, UF loadings and with or without Dricon®.

Table 2 Data of the blow torch test for kenaf particleboard

Density (Kg/m^3)	Resin (%)	Weight Loss (%) Control	8% Dricon®	12% Dricon®	% improvement 8% Dricon®	12%Dricon®
550	8	39.89	28.05	23.56	29.68	40.94
	10	35.81	26.24	25.57	26.72	28.6
	12	34.81	24.82	20.58	28.70	40.88
450	8	39.31	25.33	20.54	35.56	47.75
	10	37.72	19.6	19.88	48.04	47.30
	12	34.9	20.73	19.77	40.60	43.35
350	8	89.78	38.73	36.12	56.86	59.77
	10	50.6	35.43	29.59	29.98	41.52
	12	50.83	23.42	24.1	53.92	52.59

The effectiveness of Dricon®, UF loadings and densities on improving the fire resistance is based on the percent weight loss of the samples. The smaller the percent weight loss, the better the resistance of the samples to fire. These evaluations were made based on the comparisons made between the treated and the untreated boards. Obviously, the addition of Dricon® had significantly reduced the weight loss of the particleboards after they have been exposed to the fire source. The fire performance of the boards improved as the amount of Dricon® was increased from 8 to 12%.

Dricon® contains boron compounds and phosphorous in its formulation which work together to provide good fire protection to the treated samples. Boron compounds can penetrate deep into the particles and establish a long lasting and better protection to fire [11]. At the same time, phosphorus forms protection layers on the particles once the samples are heated, hence encouraged generation of char on the samples and reduce the rate of flaming. These findings are tally with the findings of Izran [12].

The study also showed that density and resin loading can affect the fire resistance of the boards as presented in Table 2. The samples of 550 kg/m3 showed the percent improvement of weight loss better than the control samples with the improvement was between 26.72% to 40.94%. Meanwhile, for the samples with 450kg/m^3, the percent improvement was in the range of 35.56% to 48.04%. Wider percent improvement range was recorded for 350kg/m^3 boards i.e. 29.98% to 59.77%. Lighter and thinner boards are easier to ignite and decomposed than the denser and heavier boards [11]. This might be a suitable explanation why for this study, boards with lower density exhibited higher percent weight loss compared to those with higher density for both treated and untreated boards.

Similar patterns of results were observed from the boards fabricated with different resin loadings. The percent weight loss was smaller as the resin loading was increased except for 550kg/m^3 boards treated with 12% w/w Dricon® and 450kg/m^3 boards treated with 8% Dricon®. The results of these samples were found inconsistent. For the 550kg/m^3 samples, the percent weight loss experienced a slight increase (from 23.56% to 25.57%), when the resin loading was added from 8% to 10%. But then, it decreased to 20.58% as the resin was increased to 12%. As for the 450 kg/m^3, increase of resin loading from 8% to 10% had actively reduced the percent weight loss; however the percent weight loss increased about 1.13% (19.6% to 21.73%) as addition of 2% resin loading was occupied. These indicate that, density and fire retardant can also give influences to the effects of resin loading in reducing the percent weight loss. Selection of a correct resin loading to be mixed with a board density and a fire retardant amount is essential to get a good fire performance result.

3.2 Fire Propagation Test

Table 3 shows the results of fire propagation tests. The fire performance in the fire propagation test was assessed by the propagation index value, I, which ranges from 0 to 100 in increasing order of hazard. The fire propagation index values I give a comparative measure of the amount of heat released and flame spread from a lining material within a compartment [8, 11]. A high value of I indicates greater contribution of heat release. If heat is the major contributor to hazard, it is defined as thermal hazard [7].

Table 3: Fire propagation of the kenaf particleboard

		Index of Performance (I)		
Density (Kg/m^3)	Resin (%)	Control	8% Dricon®	12% Dricon®
550	8	45.40 (3)	29.10 (2)	27.20 (2)
	10	48.10 (3)	29.60 (2)	28.60 (2)
	12	47.40 (3)	37.10 (2)	32.50 (2)
450	8	45.00 (3)	34.70 (2)	28.70 (2)
	10	43.20 (3)	31.70 (2)	24.40 (1)
	12	48.20 (3)	32.90 (2)	28.50 (2)
350	8	47.80 (3)	31.00 (2)	32.60 (2)
	10	55.10 (4)	37.70 (2)	36.40 (2)
	12	47.60 (3)	34.20 (2)	31.00 (2)

Value in the brackets was the class rating of flame spread

In all cases of the samples, either controls or those treated with Dricon®, the fire propagation index values were higher than 12 as displayed in Table 3. This is expected due to the characteristics of kenaf itself where it is categorized as low density (almost 200 kg/m^3) non-wood type. Generally, untreated timber, plywood and chipboard with density less than 400 kg/m^3 are rated as class 3 [13].

From Table 3, incorporation of Dricon® into the boards regardless of board density and UF loading found the propagation index I value dropped much greater compared to the board without Dricon®. The propagation index I for the sample of 550 kg/m^3, 450 kg/m^3 and 350 kg/m^3 density felled under category 2 and 1 and were better than untreated board which is felled under category 3 and 4. This shows that Dricon® were effective to reduce heat release as well as the spread of flame. [12, 15] also reported the same results in his study where the propagation index I of untreated particleboards presented higher value than the boron treated boards. The fire propagation study of Dricon® (boron-formulated phosphorous-based fire retardant)-treated particleboards was also done [14]. The findings of the study were that the fire performance index for the treated particleboards was under class 1 with performance index within 10 to 25. In that study, he added boron-based fire retardant in a powder form which was scattered during fabrication of the particleboards. The increase of Dricon® loading from 8% to 12% was insignificantly affect the fire performance of the boards as the index values were still remain under category 2. However, the performance index of the boards loaded with 12% Dricon was lower than boards loaded with 10% and 8% Dricon.

4. CONCLUSIONS

The treatment of kenaf core particleboard using Dricon® was effective to reduce the weight loss in blow torch test as well as prevent excessive heat release of the samples. The fire retardant was also found to work well in shorten the flame spread on the samples respectively. These findings have shown that Dricon® is a multi-function fire retardant that can protect the samples from various fire-destructing factors. The advantages provided by Dricon® can be further commercialized by incorporated this chemical in particleboards, solid woods, fibreboards and plywood made from various species in future.

REFERENCES

[1] L.W., Charles, K.B., Venita, and E.B., Robert. Kenaf harvesting and processing. ASHS Press, Alexandria, VA. 2002.

[2] W., Charles, and V.K., Bledsoe. Kenaf yield components and plant composition. National symposium on new crops and new uses. Sunnyville ave, USA. 2001.

[3] H.M., James, M.K., Andrzej, A.Y., John, C., Poo, and B., Zhaozhen. Performance of hardboards made from kenaf. Mississippi State University, USA. 1999, 31: 367-379.

[4] M.T., Paridah, A., Nor Hafizah, A., Zaidon, I., Azmi, M.Y., Mohd Nor and M.Y., Nor Yuziah. Bonding properties and performance of multi-layered kenaf board, Journal of Tropical Science 2009, 21(2):113-122.

[5] S.N., Syed Norridzuan. Improvement on Performance of Heveawood Particleboard Treated with Dricon Fire Retardant. Bac Sc. Thesis, Faculty of Forestry, UPM. 24pp.Unpublished. 2000.

[6] Anon, DRICON® Fire Retardant Treated Wood Product Handbook. Hickson Corporation, ABC Wood Preservers Anytown, U.S.A. 1991.

[7] A., Tewarson. Flammability parameters of materials: ignition, combustion and fire propagation. Journal Fire Science, 1994, 12: 329-355.

[8] B.F.W., Rogowski. The fire propagation test: Its development and application. Fire research technical paper, No 25. H.M.S.O., London, ISBN-10: 0114701407. 1970

[9] H.C., Anthony. Urea formaldehyde adhesives resins. Forest Product Laboratory, USDA Forest Service. 1996

[10] Anon, BS 476: Part 6: 1989 British Standard Fire Tests on Building Materials and Structures Part 6 Fire Propagation Test for Materials. 1989.

[11] A.M., Abdul Rashid, L.T. Chew. Fire retardant treated chipboards. Proceedings of the Conference on Forestry and Forest Products Research CFFPR-90, Forest Research Institute Malaysia, Kepong, Selangor, 1990, pp. 37

[12] K., Izran, A., Zaidon, A.M., Abdul Rashid, F.H., Abood, M.J., Saad, Z., Mohd, Z., Thirmizir, Khairul Masseat and S., Rahim S. Fire propagation and strength performance of fire retardant-treated hibiscus cannabinus particleboard. Asian Journal of Applied Sciences 2009, 2(5): 446-455.

[13] G.S., Hall. Flame retardant treatments – the state of art. Record of 1975 Annual Convention of BWPA. 1975.

[14] R., Riem, D.H., Roland, and T.A., Wilhelmus. Canadian Patent 872172. http:// patents.ic.gc.ca/opiccipo/cpd/eng/patent/872172/summary.html?type=number_search. 1971.

[15] K., Izran. Fire Performance and Properties of Particleboards made from kenaf (Hibiscus cannabinus L.) core treated with fire retardants, M Sc.thesis, Faculty of Forestry, Universiti Putra Malaysia, Unpublished. 2009.