STUDY ON ULTRAVIOLET RESISTANCE OF WOOD PLASTIC COMPOSITE PRODUCED FROM ACACIA MANGIUM BARK AND NANO TiO_2

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SUMMARY

This study determined effect of nano TiO_2 ratio on some properties of wood plastic composite (WPC), especially ultraviolet (UV) resistance of the material. Research results showed that, the TiO_2 nanoparticles did not significantly affect bonding quality between wood flour and plastic, it means when adding nanoparticles into WPC, the strength of material was almost unchanged. However, the abrasion ability of the material was significantly affected. The results revealed that, when the nano TiO_2 ratio increased, the mass loss of WPC due to abrasion reduced; therefore the abrasion resistance of WPC increased as added nano ratio increased, when the used nanoparticles ratio was 0.5%, the mass loss due to abrasion of WPC was 0.42 g/100r, but when the used nanoparticles ratio increased to 1.5%, the mass loss due to abrasion of WPC reduced to 0.31 g/100r. Moreover, adding TiO_2 into the WPC production process from *Acacia mangium* bark could increase the color stability of the material under UV radiation. The results also presented that, with the samples did not contain nano TiO_2, ΔE value was about 9 to 10, but with the samples containing TiO_2, the ΔE values reduced from 3 to 5 (40-50% reduction).

Keywords: Abrasion, color durability, UV resistance, WPC.

I. INTRODUCTION

Recent researches have shown that, acacia bark powder can used as raw materials to produce WPC with its characteristics as WPC produced from wood powder.

However, one of the remarkable disadvantages of WPC both from wood powder or bark powder is low resistance to UV when exposed to weather, the UV light from the sun quickly enhances the aging ability of the material, this severely affects the color and durability of the material when used outdoors.

Therefore, the researches on UV resistance of WPC material play an important role. Among them adding nanoparticles in the manufacturing process of material is one of the effective solutions. This method not only brings significant efficiency for UV resistance of WPC material, it is also considered to be one of the environmental friendly methods.

II. MATERIALS AND METHODOLOGY

2.1. Materials

+ Wood powder and acacia mangium bark powder with size of 2 - 4 mm; moisture of 4%.

+ Primary plastics Polyetylen, high density (HDPE).

+ Supported substance: MAPE (content of maleic anhydride – MA is 1.4% by mass).

+ Equipment used: 2-screw extruding machine ESYMASTER.

+ Mixed composition ratio as follows:

(wood powder + bark powder) : HDPE : MAPE = 43.53 (70% wood powder + 30% bark powder) : 53.22 : 3.25

+ Ratio of TiO_2 amount compared with HDPE: 0.5%; 1.0%; 1.5%

+ Press technology: Using extruded technology one stage. This technology is used popularly nowadays, and without the stage of wood - plastic granulating, wood powder and plastic materials are given directly at the same time.

+ Screw rotation speed: 24.0 r/min

+ Extruded temperature: 147^{o}C

2.2. Experimental method

Method of adding nanoparticles into WPC as follows:

MAPE was evenly dispersed in the solvent, then high-frequency ultrasonic waves were used to disperse nanoparticles in the MAPE solution.

- WPC samples used to assess UV resistance included 4 types: samples without TiO_2, samples containing 0.5% TiO_2, samples containing 1.0% TiO_2, and samples containing 1.5% TiO_2.

- Sample size: thick x width x length = 10 mm x 50 mm x 100 mm.

- UV light condition: UV light radiated directly on the sample surface in room temperature condition and air environment.

- UV radiation intensity: lamp's capacity: 40W, wavelength: 350 nm; distance from the lamp to the sample surface: 50 mm.

- The UV radiation time: 960h

- Color durability of WPC was assessed by the difference between the colour index of WPC surface, measured at the time of 960h. Specific times of colour measurement after UV radiation were: 6h, 24h, 48h, 72h, 96h, 144h, 192h, 240h, 312h, 384h, 456h, 528h, 600h, 672h, 750h, 816h, 888h, 960h.

III. RESULTS AND DISCUSSION

3.1. The characteristics of bark material used in the study

a) Thickness of bark and rate of bark-wood of *acacia mangium* according to the tree height are shown in Table 01.

Table 01. Thickness of bark and bark-wood rate of *acacia mangium* according to the tree height

Position at tree height (m)	Thickness of bark (cm)	Rate of bark-wood (%)
0	1.85	7.60
1.30	1.50	7.10
3.60	1.20	6.00
5.60	0.95	5.30
7.60	0.90	5.60
9.60	0.75	5.50
>10	0.6	5.10
Average	**1.10**	**6.03**

The Table 1 showed that, bark thickness and bark-wood rate tended to decrease according to the tree high. The average thickness of bark was about 1.1 cm, the average rate of bark was about 6.0% compared to the volume of stem.

b) Density of *acacia mangium* bark according to the tree height position are shown in Table 02.

Table 02. Density of acacia mangium bark according to the tree height position

Position at tree height	Density of bark[1] (g/cm^3)	Standard deviation
stump	0.453	0.030
stem	0.285	0.026
crown	0.189	0.042
Average	**0.309**	

Note: [1]density of bark at moisture of 12% (relative humidity 65%, temperature 20^{o}C).

The Table 2 showed that, the density of bark was significantly different at the different positions, and had the rule of change. The density of bark at higher part of the tree was smaller than that at lower position.

c) The size of the bark fiber

The sizes of the bark fiber are shown in Table 03 and Table 04.

Table 03. The distribution of the average diameter of the acacia mangium bark fiber

No	Average diameter (µm)	Frequency (%)		
		stump	stem	top
1	<=15	4.0	6.0	2.0
2	(15, 20]	36.0	50.0	58.0
3	(20, 25]	46.0	40.0	38.0
4	(25, 30]	12.0	2.0	2.0
5	>30	2.0	2.0	0.0

Table 04. The distribution the average length of the acacia mangium bark fiber

No	Average length (µm)	Frequency (%)		
		stump	stem	top
1	<=750	8.0	4.0	4.0
2	(750, 900]	16.0	16.0	12.0
3	(900, 1050]	26.0	26.0	16.0
4	(1050, 1200]	24.0	28.0	34.0
5	(1200, 1350]	16.0	20.0	24.0
6	>1350	10.0	6.0	10.0

Based on the data of diameter and length of fibers, we can see that the diameter of *acacia mangium* bark fiber at 3 positions (top, stem and stump) showed no significant difference, ranged from 19.7 µm to 21.1 µm. Fiber length ranged from 1056 µm to 1107 µm. According to the tree height from stump to the top, the length of bark fiber increased, but diameter of bark fiber reduced. Details is presented in Table 05.

Table 05. Fiber morphology of acacia mangium bark

Position at tree height	length (µm)	Standard deviation	Diameter (µm)	Standard deviation	Length/ Diameter	Standard deviation
stump	1,056	207	21.1	3.6	51	11.4
stem	1,077	194	20.0	3.5	55	11
crown	1,107	201	19.7	2.6	57	10

d) Basic chemical composition of *acacia mangium* bark

Basic chemical composition of *acacia mangium* bark is presented in Table 06.

Table 06. The basic chemical composition of acacia mangium bark (average value)

pH	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Extracts (%)		
				In cold water	In hot water	1% NaOH
5.45	17.4	25.8	24.7	14.5	19.2	49.8

The chemical composition data showed that, the cellulose content in *acacia mangium* bark was much lower than that in normal wood, and the content of the extracts in the bark was very high, this can cause a certain effect on production technology and quality of WPC made of bark powder and plastic.

3.2. The strengths of WPC

Results of WPC's strengths in this study are presented in Table 07.

Table 07. The strength criteria of WPC

No	Criteria	Amount of used nano TiO_2			
		0.5%	1.0%	1.5%	Average
1	Water absorption, %	1.32	1.30	1.32	1.31
2	Tensile strength, MPa	18.53	18.45	18.52	18.50
3	Bending strength, MPa	25.21	25.34	25.28	25.27
4	Bending elasticity module, MPa	1204	1210	1208	1207.33
5	Mass loss due to abrasion, g/100r	0.42	0.35	0.31	0.36

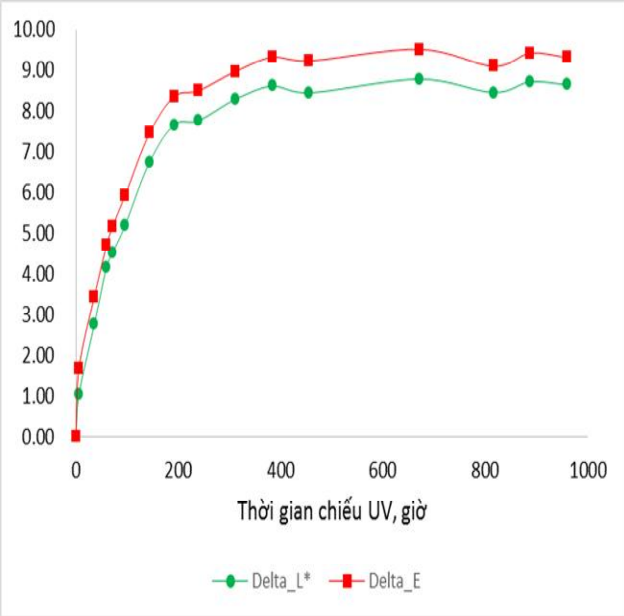
The results of determining the strength criteria of the WPC showed: when adding nano TiO_2 in the WPC, its strength changed insignificantly, this means the TiO_2 nanoparticles did not affect remarkably the strengths of the WPC material.

However, the abrasion resistance of the WPC was affected by nano TiO_2 addition. The experimental results revealed that, when the amount of used nano TiO_2 increased, the mass loss of WPC material due to abrasion reduced, therefore the abrasion resistance of the WPC increased as the ratio of used nano TiO_2 increased.

When the ratio of used nanoparticles was 0.5%, the mass loss of the WPC material due to abrasion was 0.42 g/100r, but when the ratio of used nanoparticles increased to 1.5%, the mass loss of the WPC due to abrasion reduced to 0.31 g/100r (reduction 26%). This can be explained by TiO_2 nanoparticles are a metal material, impervious to water and have high impact and abrasion resistance; hence when adding the nanoparticles into WPC material, a part of nanoparticles was dispersed evenly over the WPC's surface, thereby increasing the abrasion resistance of the surface material.

3.3. UV light resistance of WPC when adding TiO_2 nanoparticles

The results of determining the color index of WPC from *acacia mangium* bark powder and HDPE plastic after irradiated with UV during 960h is shown in Figures 01 to 04.



Time of irradiation with

Figure 01. Color change when irradiated with UV of WPC sample without nano TiO_2

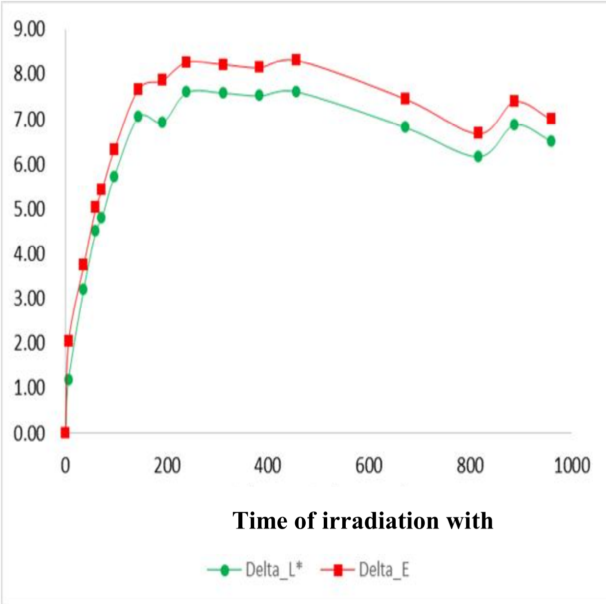


Figure 02. Color change when irradiated with UV of WPC sample containing 0.5% TiO_2

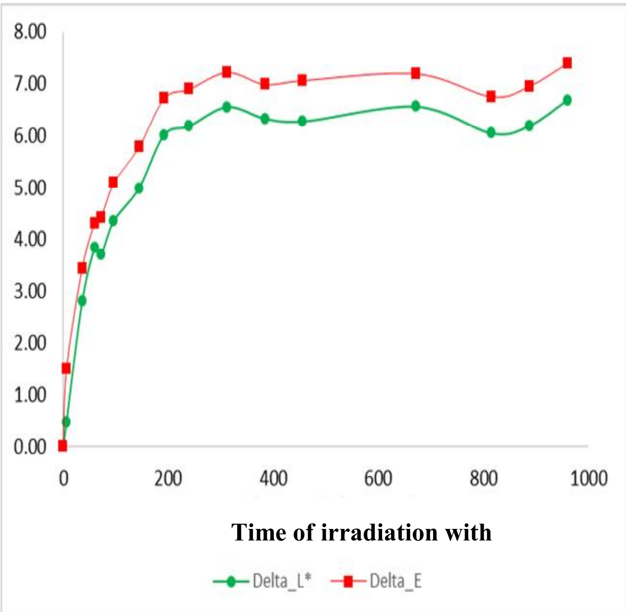


Figure 03. Color change when irradiated with UV of WPC sample containing 1.0% TiO_2

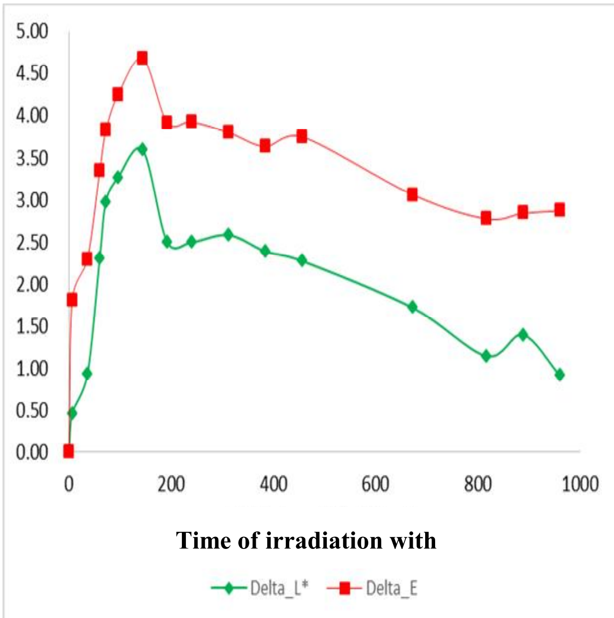


Figure 04. Color change when irradiated with UV of WPC sample containing 1.5% TiO_2

The experimental results exposured that the brightness (L*) of the samples after irradiated by UV changed very clearly and followed a rule. Moreover, when the amount of used nano TiO_2 increased in the WPC samples, the brightness change (ΔL) reduced from 7 - 9 down to 1 - 3.

Total color deviation (ΔE) of the WPC samples not containing TiO_2 and the WPC samples containing TiO_2 also had a change tendency similar as ΔL. With the WPC samples not containing TiO_2, the ΔE varied from 9 to 10, but with the WPC samples containing TiO_2 the ΔE reduced about 40-50% (ΔE from 3 to 5). This means: adding nano TiO_2 into the production process of WPC from *acacia mangium* bark can enhance the color stability of WPC irradiated by UV. This is consistent with similar studies in the world, because TiO_2 nano material themselves always possesses reflective ability (approximately 98%), therefore when nanoparticles appear on material surface, they contribute significantly to UV reflection from the light to the material surface.

With this result we may recommend, the outdoor WPC production process from *acacia mangium* bark should be added a certain amount of nano TiO_2 (range from 1.0% to 1.5% compared to HDPE), this could be a new research direction in the future to prolong service life of WPC material from *acacia mangium* bark and HDPE plastic.

IV. CONCLUSIONS

From the research results, there are some conclusions:

- *Acacia mangium* bark can replace about 30% of wood powder used in the WPC production, with such rate of used bark powder, the WPC products met the requirements of interior and exterior furniture manufacture.

- When adding TiO_2 nanoparticles into WPC, it basically did not affect the strengths of material, only abrasion resistance was affected; as the ratio of used nanoparticles was 0.5%, the mass loss of the WPC material due to abrasion was 0.42 g/100r, but when the ratio of used nanoparticles increased to 1.5%, the mass loss of the WPC due to abrasion reduced to 0.31 g/100r (abrasion resistance of the material increased 26%).

- When adding TiO_2 nanoparticles into the manufacturing process of WPC from *acacia mangium* bark, the color stability under UV radiation of the WPC material could be increased, when the rate of used nanoparticles was 1.5%, the ΔE value reduced to 40-50% (compared to the control samples).

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NGHIÊN CỨU KHẢ NĂNG CHỊU TIA UV CỦA VẬT LIỆU COMPOSITE GỖ NHỰA TỪ BỘT VỎ CÂY KHI THÊM HẠT NANO TiO_2

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TÓM TẮT

Nghiên cứu này xác định được khả năng ảnh hưởng của tỷ lệ hạt nano TiO_2 cho vào đến một số tính chất của vật liệu WPC, đặc biệt là làm tăng khả năng chịu tia UV của vật liệu. Kết quả nghiên cứu cho thấy, hạt nano TiO_2 không có ảnh hưởng đáng kể đến khả năng liên kết giữa bột gỗ và nhựa, tức là khi cho hạt nano vào thì các chỉ tiêu về độ bền của vật liệu cơ bản không thay đổi. Tuy nhiên, về chỉ tiêu độ mài mòn của vật liệu lại có ảnh hưởng rõ rệt. Kết quả cho thấy, khi tỷ lệ sử dụng hạt Nano tăng lên thì khối lượng tiêu hao khi mài mòn của vật liệu WPC giảm xuống, tức là khả năng chịu mài mòn của vật liệu tăng lên khi tỷ lệ Nano sử dụng tăng lên, khi tỷ lệ hạt nano sử dụng là 0,5% thì khối lượng tiêu hao khi mài mòn của vật liệu là 0,42 g/100r, nhưng khi tỷ lệ Nano sử dụng tăng lên đến 1,5% thì khối lượng này giảm xuống còn 0,31 g/100r. Ngoài ra, khi cho thêm TiO_2 vào trong quá trình sản xuất WPC từ vỏ cây Keo tai tượng có thể làm tăng độ ổn định màu sắc của vật liệu khi chiếu tia UV. Kết quả cho thấy, với mẫu không chứa TiO_2 thì ΔE có giá trị khoảng 9 đến 10, nhưng với mẫu chứa TiO_2 thì giá trị ΔE giảm xuống còn khoảng 3 đến 5 (tức giảm 40-50%).

Từ khóa: Chịu tia UV, độ bền màu, độ mài mòn, WPC.

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