Transactions on Science and Technology Vol. 5, No. 2, 184 - 189, 2018

Effect of Plastic Content Ratio on the Mechanical Properties of Wood-Plastic Composite (WPC) Made From Three Different Recycled Plastic and Acacia Fibres

Verra Gulitah#, Kang Chiang Liew

Faculty Science of Natural Resources, Forestry Complex, Universiti Malaysia Sabah, Jalan UMS, 88400, Kota Kinabalu, Sabah, MALAYSIA

Corresponding author. E-Mail: Verra_bb@yahoo.com; Tel: +6014-551 4399

ABSTRACT Recycled plastic as a matrix in Wood-Plastic Composite (WPC) has been one of the major interesting research subjects due to its availability and for the sake of environmental concern. In this study, the effect of different ratios (100%, 90%, 80%, 70%, 60% and 50%) of plastic content from polypropylene (PP), high density polyethylene (HDPE) and low density polyethylene (LDPE) mixed with wood fibres (WF) from Acacia were used to produce WPCs and evaluated for their mechanical properties. The composite test pieces were produced by hot-press method and mould which followed ASTM D638-02 and ASTM D790-02 for tensile properties and flexural properties respectively. It was found that the performance of tensile strength was linearly increased with increasing amount of plastic content. WPCs of PP-WF, HDPE-WF and LDPE-WF having 100% plastic content showed highest tensile strength which were 25.02 N/mm², 16.41 N/mm² and 12.45 N/mm² respectively for different recycled plastic. Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) results showed that WPC with 100% PP had the highest with 1020.07 N/mm² for MOE followed by 417.30 N/mm² and 371.81 N/mm² respectively for 100% HDPE and 100% LDPE. MOR showed highest for 100% PP also with 25.10 N/mm² as compared to HDPE only achieved 12.54 N/mm² and LDPE with 10.66 N/mm².

KEYWORDS: Wood-plastic composite, Acacia fibre, Recycled plastic, Plastic content, Mechanical properties

I Received 20 April 2018 **II Revised** 14 June 2018 **II Accepted** 17 June 2018 **II Online** 28 June 2018 **I**

TRANSACTIONS ON SCIENCE AND TECHNOLOGY

INTRODUCTION

In the past years, the Wood-Plastic Composite (WPC) has attracted much attention as a favorable sector in composite and polymer industry. WPC is synonym with the reinforcement of virgin or recycled plastic with natural filler such as wood flour or wood fibre. The common recycled plastics used for the production of WPCs are Polypropylene (PP), High and Low density polyethylene (HDPE and LDPE), Polystyrene (PS) and Poly Vinyl Chloride (PVC). Either virgin plastics or recycled plastics, as long as they can melt and can be processed below the degradation temperature of wood (200°C), hence they meet the requirement of producing WPCs (Najafi *et al*., 2006).

The relationship between recycled plastic and wood fibre has been widely investigated by several researchers. Jayaraman & Bhattacharyya (2004) have evaluated recycled plastic HDPE from post-consumer waste stream can be used well in producing WPCs. While Atuanya *et al*. (2011) investigated that the MOE and MOR of the WPCs increased with the increase of plastic content of recycled LDPE as it can totally cover wood fibres. Besides, the mechanical properties of WPCs was influenced by the size of wood fibres. A large form of wood fibres would face difficulty during the dispersion in the plastic matrix (Rahman *et al*., 2013).

The idea about the development of WPCs was because to overcome an environmental issue caused by the increasing amount of municipal solid wastes which is mostly come from plastic wastes. As we know that, plastic wastes are non-biodegradable and took a longer time to be decomposed. Therefore, the uses of recycled plastic is significant in reducing the environmental impact and able to give a value in composite industry (Keskisaari & Ka, 2017). The purpose of this study was to investigate the mechanical properties of WPCs made from Acacia fibre and recycled plastics of PP, HDPE and LDPE which were affected by different ratio between the plastic content and the wood fibres loading. Interested readers may refer to similar investigation previously published in Basil Gungguk & Liew (2016) and also M Sujuthi & Liew (2016) on other type of materials.

METHODOLOGY

Materials

Three different types of recycled plastic namely Polypropylene (PP), High density polyethylene (HDPE) and Low density polyethylene (LDPE) from waste household were collected while screened wood fibres (Acacia species) with mesh size of 212 ɥm were acquired from Forestry Complex at Universiti Malaysia Sabah. These wood fibres were dried in an oven at 105±2°C for 24 hours. Recycled plastics from Polypropylene (PP), High density polyethylene (HDPE) and Low density polyethylene (LDPE) and wood fibres (WF) were weighed and bagged according to combination given in Table 1.1.

Table 1. Composition of PP-WF, HDPE-WF and LDPE-WF composites

PP/HDPE/LDPE content (%)	Wood fibre content (%)	Weight of recycled plastic (g)	Weight of wood fibre (g)
100	0	15	0
90	10	13.5	1.5
80	20	12	3
70	30	10.5	4.5
60	40	9	6
50	50	7.5	7.5

Note: WF = Wood fibres , PP = Polypropylene, HDPE = High density polyethylene, LDPE = Low density polyethylene

Test Piece Preparation

First of all, recycled plastics and wood fibres were placed in an aluminum plate of hot-press for mixing process for 5 minutes. The pressing temperature for PP,HDPE and LDPE were 180°C, 170°C and 130°C respectively as demonstrated by some researchers (Huang & Zhang, 2009; Haq & Srivastava, 2016; Atuanya *et al*., 2011). The mixtures were then cooled to room temperature before manually chopped into pellet form. These pellets were placed into a mould with dumbbell-shape and rectangular bar shape before the final pressing. The dimension of the shape were accordance to American Society for Testing and Materials (ASTM) standard specifications.

Mechanical Test

Tensile and flexural properties of WPCs were evaluated according to ASTM D638-98 and ASTM D790-90 specifications respectively using Universal Testing Machine. Cross-head speed was set to 5 mm/min and 1.6 mm/min for tensile and flexural test respectively. All test pieces were conditioned at constant temperature (25°C) and relative humidity (65%) prior to testing. There were fifteen test pieces tested for each test (Najafi *et al*., 2006).

Statistical Analysis of Data

Statistical analysis was done by using Statistical Product and Service Solution (SPSS 20). The significance of different treatments was determined by Post Hoc (LSD) test.

RESULTS AND DISCUSSION

The mechanical properties of wood-plastic composites (WPC) made from Polypropylene (PP), High density polyethylene (HDPE) and Low density polyethylene (LDPE) and wood fibres (WF) were shown in Table 1. Statistical analysis illustrated significant differences ($P \leq 0.05$) for tensile strength, modulus of elongation (MOE) and modulus of rupture (MOR) among the wood-plastic composites for different combination.

Table 2. Mechanical properties of Wood-Plastic Composites

Ratio	Polypropylene-Wood Fibres			High density polyethylene-Wood Fibres			Low density polyethylene-Wood Fibres		
	TS (N/mm^2)	MOE (N/mm^2)	MOR (N/mm^2)	TS (N/mm^2)	MOE (N/mm^2)	MOR (N/mm^2)	TS (N/mm^2)	MOE (N/mm^2)	MOR (N/mm^2)
100:0	25.02 a (2.67) x	1020.07 a (214.64)x	25.10 a (3.92)x	16.41 a (2.39)y	423.27 a (72.67)yz	12.50a (2.15)y	11.88a (0.25)z	372.42a (78.35)yz	9.18a (1.36)z
90:10	15.00 b (2.08) x	1008.85 a (188.14) x	21.12 b (2.65) x	12.01 b (1.87)y	357.82 b (48.52)y	9.12b (1.76)y	8.46b (0.49)z	257.70b (22.35)z	4.87b (0.65)z
80:20	12.34 c (1.90) x	997.18 a (138.11)x	15.55 c (3.06) x	9.40 c (1.56) y	281.74 c (26.09)y	8.21 b (1.18)y	6.92c (0.25)z	180.97c (11.73)z	3.72c (0.41)z
70:30	11.39 ce (1.01) x	953.50 a (298.34) x	11.97 d (3.09) x	7.87 d (0.63) y	255.63 c (6.45)yz	4.63d (1.32)y	5.55d (0.44)z	175.02dc (38.87)yz	2.64d (1.17)z
60:40	10.64 e (0.67) x	883.46 a (358.30)x	11.81 d (2.86) x	7.44 d (0.65) y	178.41 e (33.74)yz	3.52e (0.58)y	3.02e (0.60)z	172.01ec (17.83)yz	2.30d (0.36)y
50:50	7.87 f (1.29) x	520.81 b (233.69)x	5.55 f (1.83) x	5.14 f (0.47) y	176.19e (55.30)yz	2.00 f (0.47)y	2.13f (0.18)z	162.66fc (26.75)yz	2.11d (1.13)y

Note: TS = Tensile strength, MOE = Modulus of elongation, MOR = Modulus of rupture
Values in parenthesis were standard deviation. The different alphabets a, b, c, d and e in each column for the different ratio was significant at $p \leq 0.05$. The different alphabets x, y and z in each row for the same ratio was significant at $p \leq 0.05$.

Figure 1 showed the tensile properties of PP-WF, HDPE-WF and LDPE-WF composites. From Figure 1, it shows that tensile strength decreased as the plastic content decreased from 10 to 50 % in the composition. Statistical analysis showed that there was significant difference ($p \leq 0.05$) in tensile strength among the wood-plastic composite (Table 1.2). The finding might due to the wood fibre were not fully bonded with the plastic matrix during the mixing process. Previous studies have reported that the lower tensile strength of the composites is due to the weak interfacial bonding between wood fibre filler and matrix plastic (Ashori & Nourbakhsh, 2009; Sihombing *et al.*, 2012). This is an incompatibility phenomena between wood fibres which are hydrophilic in nature and plastics are hydrophobic when they were reinforced or mixed together.

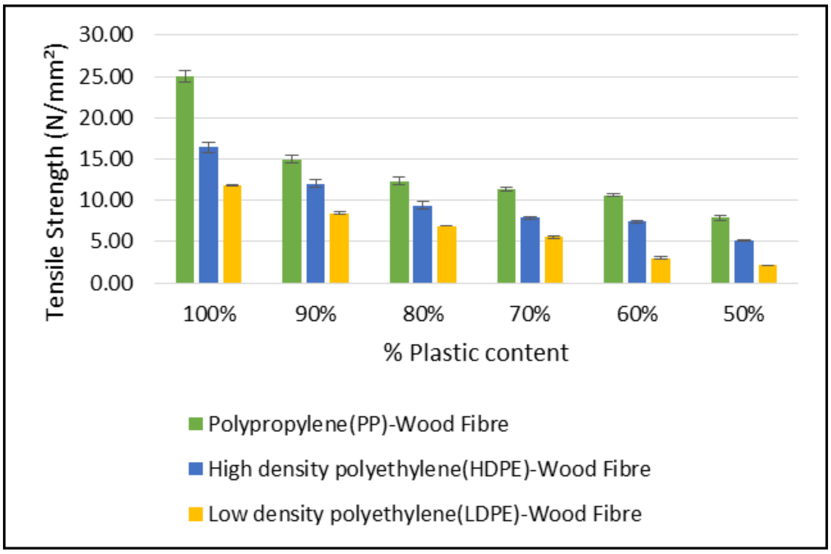

Figure 1. Effect of different plastic content on tensile strength of Wood-Plastic Composite produced

Figure 2 showed the value of MOE decreased when the plastic content decreased from 10% to 50% in the composition for PP-WF, HDPE-WF and LDPE-WF composites. It can be observed that the MOE of composites made from PP-WF exhibited higher MOE compared to HDPE-WF and LDPE-WF composites. Statistical analysis showed that there was significant difference ($p \leq 0.05$) in tensile strength among the wood-plastic composite (Table 1.2). For 100% plastic content of PP-WF, composites had the highest MOE value that was 1020.07 N/mm² while 100% plastic content of HDPE-WF and LDPE-WF shows that the value of MOE were 423.27 N/mm² and 371.42 N/mm² respectively. No difference between 100% plastic content of HDPE-WF and LDPE-WF was observed. The findings suggested that poor interfacial bonding between wood fibres and plastic matrix is due to the size of the wood fibres. When the wood fibres cannot bond well with plastic matrix, some void areas will occur which decreased the strength of the composite. Furthermore, Sihombing *et al.* (2012) concluded that fine particles can flow well within the composite and lead to a better bonding between fibre and matrix.

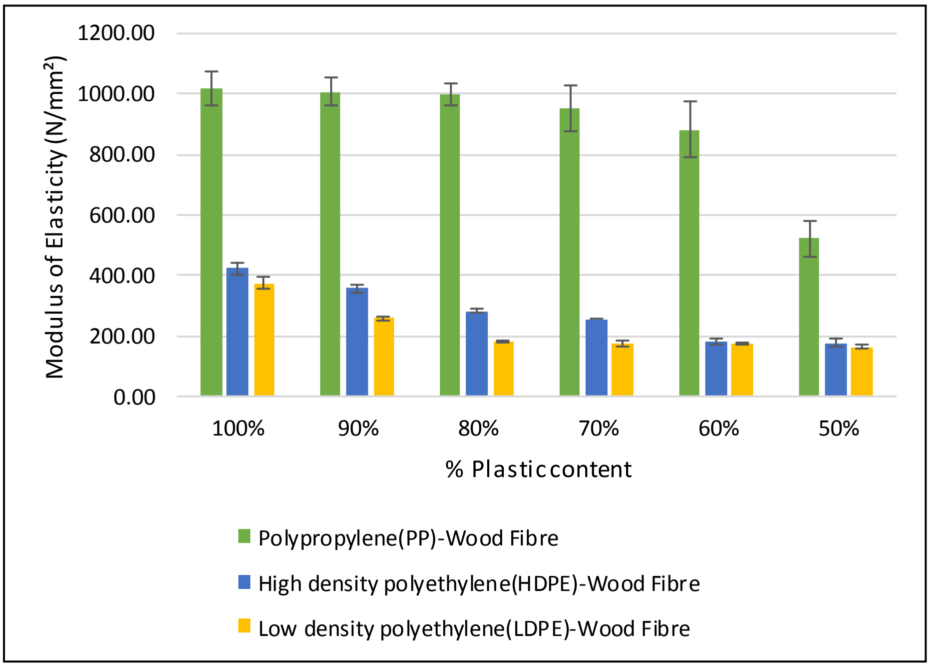

Figure 2. Effect of different plastic content on Modulus of Elasticity (MOE) of Wood Plastic Composites produced

Figure 3 illustrated the MOR of the composites decreased with the decreased of plastic content and exhibited a similar trend as the MOE of the WPCs. The composites has a MOR that ranged from 2.11 to 25.10 N/mm². Statistical analysis showed that there was significant difference ($p \leq 0.05$) in tensile strength among the wood-plastic composite (Table 1.2). The ratio of 50:50 for PP-WF, HDPE-WF and LDPE-WF had the lowest MOR value compared to the other formulations. Due to the intramolecular bonding among the fibers, wood fibers tend to form large aggregates during the processing of WPCs. Rahman *et al*. (2013) suggested that the wood fibres were not dispersed uniformly in the plastic matrix.

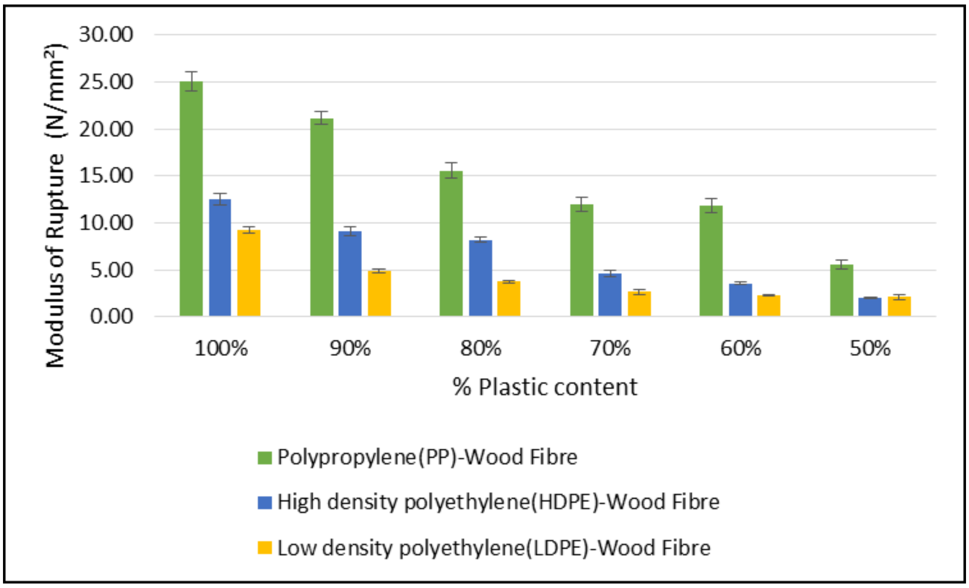

Figure 3. Effect of different plastic content on Modulus of Rupture (MOR) of Wood-Plastic Composites produced

CONCLUSION

This study was set out to determine the effect of plastic content on the mechanical properties of PP-WF, HDPE-WF and LDPE-WF. The findings can be summarized as follow: The mechanical properties of PP-WF showed the highest value in tensile strength, MOE and MOR compared to HDPE-WF and LDPE-WF. With increasing of the plastic content for each formulation, mechanical properties of wood –plastic composites also increased.

ACKNOWLEDGEMENTS

The authors would like to acknowledge with thanks the support from Faculty of Science and Natural Resources and Universiti Malaysia Sabah (UMS), Sabah.

REFERENCES

[1] Ashori, A., & Nourbakhsh, A. (2009). Characteristics of wood-fiber plastic composites made of recycled materials. *Waste Management*, **29**(4), 1291–1295.

[2] Atuanya, C. U., Ibhadode, A. O. A., & Igboanugo, A. C. (2011). Potential of using recycled low-density polyethylene in wood composites board. *African Journal of Environmental Science and Technology*, **5**(5), 389-396.

[3] Gungguk, D. B. & Liew, K. C. (2016). Application of Industrial Cement in the Durability of Degradable Bioplastic Pot. *Transactions on Science and Technology*, **3**(1-2), 238-243.

[4] Haq, S., & Srivastava, R. (2016). Wood Polypropylene (PP) Composites Manufactured by Mango Wood Waste with Virgin or Recycled PP : Mechanical , Morphology , Melt Flow Index and Crystalline Behaviour. *Journal of Polymers and the Environment,***25**(3), 640-648.

[5] Huang, H. X., & Zhang, J. J. (2009). Effects of filler-filler and polymer-filler interactions on rheological and mechanical properties of HDPE-wood composites. *Journal of Applied Polymer Science*, **111**(6), 2806–2812.

[6] Jayaraman, K., & Bhattacharyya, D. (2004). Mechanical performance of woodfibre – waste plastic composite materials. *Resources, Conservation and Recycling* ,**41**,307–319.

[7] Kazemi Najafi, S., Tajvidi, M., & Hamidina, E. (2007). Effect of temperature, plastic type and virginity on the water uptake of sawdust/plastic composites. *Holz Als Roh - Und Werkstoff*, **65**(5), 377–382.

[8] Keskisaari, A., & Ka, T. (2017). Raw material potential of recyclable materials for fiber composites : a review study, *Journal of Material Cycles and Waste Management* **19**(3),1136–1143

[9] Sujuthi, R. A. F. M. & Liew, K. C. (2016). Properties of Bioplastic Sheets Made from Different Types of Starch Incorporated With Recycled Newspaper Pulp. *Transactions on Science and Technology*, **3**(1-2), 257-264.

[10] Najafi, S. K., Hamidinia, E., & Tajvidi, M. (2006). Mechanical properties of composites from sawdust and recycled plastics. *Journal of Applied Polymer Science*, **100**(5), 3641–3645.

[11] Rahman, K.-S., Islam, M. N., Rahman, M. M., Hannan, M. O., Dungani, R., & Khalil, H. A. (2013). Flat-pressed wood plastic composites from sawdust and recycled polyethylene terephthalate (PET): physical and mechanical properties. *SpringerPlus*, **2**, 629.

[12] Sihombing, H., Rassiah, K., Ashaari, Z., & Mohd Yuhazri, Y. (2012). Analysis and development of recycled materials for wood plastic composite product. *Elixir Mech. Engg*, **51**, 10834–10840.

ISSN 2289-8786. http://transectscience.org/