PHYSICAL AND MECHANICAL PROPERTIES OF WOOD PLASTIC COMPOSITE (WPC) MADE FROM THREE DIFFERENT PLASTIC WASTE CODES AND ACACIA WOOD FLOUR

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FACULTY OF SCIENCE AND NATURAL RESOURCES
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DECLARATION

I hereby declare that the material in this thesis is my own expect for the citation, equations and references which have been fully acknowledgement.

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CERTIFICATION

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VIVA DATE	:	**28 JUNE 2019**

CERTIFIED BY

SUPERVISOR Signature

Associate Professor Dr. Liew Kang Chiang

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ABSTRACT

Over the past years, wood plastic composite (WPC) has been a favourite topic among the researchers. The main reason for the use of plastic wastes in producing WPC was because of the environmental concern and the availability of wood flour. In this study, three types of WPC were produced by using three different plastic waste codes combine with Acacia wood flour namely polypropylene-wood flour (PP-WF), high density polyethylene-wood flour (HDPE-WF) and low density polyethylene-wood flour (LDPE-WF) with different plastic content at 100%, 90%, 80%, 70%, 60% and 50%. Plastic waste particles and wood flour were mixed and melted together by using Hot-press machine. Later the mixture which were in mat-form were cut into small sheet before placed in a mould where the dimension of test piece followed American Society for Testing and Materials (ASTM) D638-02 and D790-02 standard specifications. The effect of plastic contents on physical, mechanical and morphological properties of all type of WPC were investigated in this study. The moisture content of the WPC increased along with the increase of wood flour content from 10% to 50%. Among the three different types of plastic waste codes, PP with 100% plastic content had the highest density (1.033 g/cm³) followed by 100% plastic content of LDPE (0.87 g/cm³) and HDPE (0.863 g/cm³) at 100% plastic content. Water absorption and thickness swelling increased more than 50% and 4% respectively as the plastic content decreased at 50%. Results showed that as the plastic content decreased, the tensile strength, Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) also decreased. Plastic waste codes of PP, HDPE and LDPE at 100% plastic content showed 25.02 N/mm², 16.41 N/mm² and 12.45 N/mm² of tensile strength respectively and showed significant difference at $p \leq 0.05$. Similar findings for MOE and MOR, the trend result also decreased as the plastic content decreased. Range value of MOE for PP-WF composite was 1020.07 N/mm² to 520.81 N/mm², while HDPE-WF and LDPE-WF composite achieved 423.27 N/mm² to 176.19 N/mm² and 372.42 N/mm² to 162.66 N/mm² respectively. Based on the results obtained in this study, the mechanical and physical properties of WPCs influenced by the plastic contents. The mechanical properties of PP-WF composite were higher than HDPE-WF and LDPE-WF composites.

ABSTRAK

CIRI-CIRI FIZIKAL DAN MEKANIKAL KOMPOSIT PLASTIK KAYU YANG DIPERBUAT DARIPADA TIGA JENIS KOD BAHAN BUANGAN PLASTIK DAN TEPUNG KAYU AKASIA

Sejak beberapa tahun yang lalu, komposit plastik kayu (WPC) telah menjadi topik kegemaran dalam kalangan penyelidik. Sebab utama penggunaan bahan buangan plastik dalam penghasilan WPC adalah kerana kesedaran alam sekitar dan gentian kayu yang mudah didapati. Dalam kajian ini, tiga jenis WPC dihasilkan dengan menggunakan tiga jenis bahan buangan plastik yang dicampurkan dengan tepung kayu Akasia iaitu polipropilena-tepung kayu (PP-WF), polietilena berketumpatan tinggi-tepung kayu (HDPE-WF) dan polietilena berketumpatan rendah-tepung kayu (LDPE-WF) dengan kandungan plastik yang berbeza pada 100%, 90%, 80%, 70%, 60% dan 50%. Bahan buangan plastik dan tepung kayu telah dicampur dan dicairkan bersama dengan menggunakan mesin tekanan panas. Kemudian campuran yang dalam bentuk hamparan telah dipotong menjadi partikel kecil sebelum diletakkan dalam acuan di mana dimensi bahan uji mengikut spesifikasi standard ASTM D638-02 dan ASTM D790-02. Kesan kandungan plastik pada sifat fizikal, morfologi dan mekanikal untuk semua jenis WPC telah disiasat dalam kajian ini. Kandungan lembapan komposit kayu plastik semakin meningkat dengan pertambahan kandungan tepung kayu dari 10% ke 50%. Antara tiga jenis kod bahan buangan plastik, PP dengan kandungan plastik 100% mempunyai ketumpatan tertinggi (1.03 g/cm^3) diikuti dengan kandungan plastik 100% LDPE (0.87 g/cm^3) dan HDPE (0.86 g/cm^3) pada kandungan plastik 100%. Keputusan menunjukkan bahawa apabila kandungan plastik menurun, penyerapan air dan pembengkakan ketebalan meningkat masing-masing dengan nilai lebih daripada 50% dan 4%. Manakala kekuatan tegangan, MOE (Modulus kekenyalan) dan MOR (Modulus pecahan) menurun apabila kandungan plastik menurun. Kod bahan buangan plastik iaitu PP, HDPE dan LDPE pada kandungan plastik 100% masing-masing menunjukkan 25.02 N/mm^2, 16.41 N/mm^2 dan 12.45 N/mm^2 untuk kekuatan tegangan dan menunjukkan perbezaan ketara pada $p \leq 0.05$. Keputusan yang sama untuk MOE dan MOR, tren graf juga menurun apabila kandungan plastik berkurangan. Nilai MOE untuk komposit PP-WF adalah 1020.07 N/mm^2 sehingga 520.81 N/mm^2, manakala komposit HDPE-WF dan LDPE-WF mencapai 423.27 N/mm^2 sehingga 176.19 N/mm^2 dan 372.42 N/mm^2 sehingga 162.66 N/mm^2 . Berdasarkan hasil yang diperolehi dalam kajian ini, sifat fizikal dan mekanikal WPC dipengaruhi oleh kandungan plastik. Sifat mekanik komposit PP-WF lebih tinggi daripada komposit HDPE-WF dan LDPE-WF.

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LIST OF SYMBOLS

%	Percentage
° C	Degree Celsius
g	Gram
mm	Milimeter
cm	Centimeter
N	Newton

LIST OF ABBRERIATIONS

ASTM	America Society for Testing and Materials
WPC	Wood Plastic Composite
PP	Polypropylene
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
PET	Polyethylene terephthalate
MOE	Modulus of Elasticity
MOR	Modulus of Rupture
WA	Water Absorption

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CHAPTER 1

INTRODUCTION

Labisia pumila or commonly known as Kacip Fatimah in Malaysia is a herbaceous plant widely used in folk medicine for facilitating childbirth and post-partum recovery (Bodeker, 2009). The phytochemical constituents of this herb have been well documented with phenolics and flavonoids being the main compounds (Norhanisah *et al.*, 2013). Several scientific studies reported that *L. pumila* possesses biological activities such as antioxidant (Norhaiza *et al.*, 2009; Karimi *et al.*, 2011), anti-carcinogenic (Pihie *et al.*, 2011), anti-microbial (Karimi *et al.*, 2011), antifungal and anti-inflammatory activities (Karimi *et al.*, 2013).

Considering the interesting pharmacological values that *L. pumila* has to offer, raw materials of this herb is highly demanded for commercial production. However, the propagation and growth rate of wild *L. pumila* is rather slow and time consuming (Mohd. Noh *et al.*, 2002; Jaafar *et al.*, 2009). Hence, a propagation system that can supply *L. pumila* continuously must be established to accommodate the demand of bioactive compounds synthesised by this herb.

Plant cell culture is an ideal biotechnological approach for secondary metabolites production as it produce continuous and reliable source of plant-based pharmaceutical products (Rao & Ravishankar, 2002; Yue *et al.*, 2016). Research to date has successfully produces high yielding cultures from various medicinal plants in either undifferentiated or differentiated cultures (Yue *et al.*, 2016). Undifferentiated cell suspension cultures lack stability and uniformity (Habibi *et al.*, 2017) which resulted in lower production of high value natural products (Yue *et al.*, 2016). In contrast, organ culture, especially adventitious root culture is more favourable due to its fast growth and stable production of secondary metabolites (Murthy *et al.*, 2008; Habibi *et al.*, 2017).

Establishment of organ cultures that produce large amounts of biomass with increased accumulation of secondary metabolites is possible through specific strategies (Murthy *et al.*, 2014a). These includes the selection of high-yielding clones, optimisation of medium composition such as type of basal medium, carbon source and plant growth regulators; and physical factors such as temperature, medium pH, agitation and aeration. Other approaches such as elicitation, precursor feeding, permeabilisation and immobilisation could also assist with the accumulation of metabolites (Abouzid, 2014; Malik *et al.*, 2014; Murthy *et al.*, 2014a; Ali *et al.*, 2016; Yue *et al.,* 2016; Andrews & Robert, 2017).

Through optimisation of *in vitro* culture conditions of adventitious root culture, high product concentration and efficacy can be achieved from the continuous source of secondary metabolites of root cultures (Murthy & Praveen, 2012). This study will highlight some of the strategies undertaken to increase *L. pumila* adventitious root metabolites yield including selection of clones, optimisation of plant growth regulators, MS medium strength and carbon source; and also elicitation. Initiation of organ cultures began with selecting parent plants that showed higher contents of the desired secondary product for organ induction (Murthy *et al.*, 2014a). The selection of a specific organ for the induction of *in vitro* adventitious roots is essential as the accumulation of metabolites varies in different organs of the same species. Following selection of high performing organ lines, another key consideration is to establish optimum media and culture composition (Ochoa-Villarreal *et al.*, 2016). Typical modifications to the adventitious root culture medium include the addition of phytohormones (Wu *et al.*, 2006; Baque *et al.*, 2010a; Fazal *et al.*, 2014), modification of the salt strength (Baque *et al.*, 2010b; Li *et al.*, 2015; Deepthi & Satheeshkumar, 2017) and sugar concentration (Baque *et al.*, 2012; Yin *et al.*, 2013; Li *et al.*, 2015). In addition, metabolite production in organ cultures can be stimulated *in vitro* by adding elicitors into the culture medium as metabolites are produced by plants in response to the imposed stresses (Naik & Al-Khayri, 2016; Andrews & Robert, 2017).

Apart from producing secondary metabolites, adventitious root can also serve as a reliable micropropagation method in tissue culture especially when numerous small shoots arise rapidly from each explant, hence leading to high rate of propagation. Previous studies on shoot regeneration of *L. pumila* only focused on leaf and stem explants (Hartinie, 2007; Ling *et al.*, 2013; Ozayanna, 2015; Syafiqah *et al.*, 2016). No attempt was done to explore the potential of adventitious roots explants of *L. pumila* for shoot regeneration purpose.

Therefore, the present study has focused on the aforementioned strategies to produce bioactives from adventitious root cultures of *L. pumila* with antioxidative properties. In addition, the potential of adventitious root explants of *L. pumila* for producing new shoots will also be investigated. The objectives of the study are;

i) To select superior *in vitro* source materials from each variety of *L. pumila* (var. *alata*, var. *pumila* and var. *lanceolata*) for high antioxidative properties
ii) To evaluate the effects of exogenous hormones, MS medium strength, sugar and elicitors on the biomass and secondary metabolites production from adventitious roots of *L. pumila* selected clones
iii) To regenerate shoots from adventitious root explants of *L. pumila*

CHAPTER 2

LITERATURE REVIEW

2.1 *Labisia pumila* (Bl.) Fern. Vill

2.1.1 Origin, distribution and taxonomy of *Labisia pumila*

Labisia pumila (Bl.) Fern. Vill is herbaceous plant which grows wildly in the rain forest of Malaysia, Indochina, Thailand and Papua New Guinea (Sunarno, 2005). The distribution of *L. pumila* is shown in Figure 2.1. In Malaysia, this herb is usually known as Kacip Fatimah. Other local names of *L. pumila* include Selusoh Fatimah, Kacit Fatimah, Tadah Matahari and Mata Pelanduk Rimba (Sunarno, 2005; Jamal, 2006).

Figure 2.1 : Distribution of *L. pumila*

Source : Global Biodiversity Information Facility (GBIF) Secretariat (2016)

According to Sunarno (2005), there are eight varieties of *L. pumila* namely var. *alata*, var. *discoplacenta*, var. *gladiata*, var. *lanceolata*, var. *pumila*, var. *malintangensis*, var. *neriifolia* and var. *sessilifolia*. Among these eight varieties, only var. *alata,* var. *pumila* and var. *lanceolata* are well-known in Malaysia (Stone, 1990). These three varieties can be distinguished from each other via their petiole and leaf physical appearances (Sunarno, 2005).

The taxonomy of *L. pumila* is shown in Table 2.1. *Marantodes pumilum* (Blume) Kuntze is a heterotypic synonym of *L. pumila* that has been accepted by The Plant List (2013). This name was originally found in Post and Kuntze (1903) as accepted taxon in the genus Marantodes (family Primulaceae). Myrsinaceae and Primulaceae are two best known families in Ericales. The taxon limits of Myrsinaceae and Primulaceae have been substantially changed, therefore the limits of Primulaceae was extended based on numerous synapomorphies within the group (Mabberly, 2008; Bremer *et al*., 2009).

Table 2.1: Taxonomy of *L. pumila*

Taxonomy	
Domain	Eukaryota
Kingdom	Plantae
Phylum	Magnoliophyta
Class	Magnoliopsida
Order	Ericales
Family	Myrsinaceae
Genus	Labisia
Species	*Labisia pumila*

Source: Global Biodiversity Information Facility (GBIF) Secretariat (2016)

2.1.2 Morphological description

Wild *L. pumila* usually grows in habitat with humus-rich soils, sandy loam and sometimes in deep clay soil or granite soils. This plant is able to grow until 60 cm in height and carries four to twelve leaves per plant. Its leaf size is approximately around 5 to 35 cm long and 2 to 8 cm wide. In addition, *L. pumila* also produced flower and fruits. Their whites to pinkish flowers are quite small which grow in spike like panicle or small clusters. Meanwhile, the size of the fruit is about 0.5 cm in diameter which changes colour from green to red or purple when ripen (Stone, 1988; Zhari *et al.*, 1999; Sunarno, 2005). The comparison of morphological characteristics and the habitat of the three varieties of *L. pumila* are shown in Table 2.2. Figure 2.2 shows the three varieties of *L. pumila* which were grown in the field.

Table 2.2: Morphological characteristics and habitat of *L. pumila*

Variety	var. *alata*	var. *pumila*	var. *lanceolata*
Petiole shape	Broad winged	Slightly winged	Terete
Length of petiole	5-12 cm	4-15 cm	6-21 cm
Length of anther	0.8 mm	1.2 mm	0.8 mm
Habitat	Lowland primary forests, shady secondary forest	Shady rain forests, edge of swampy forests	Shady primary forests, secondary and mossy forests

Source: Sunarno (2005)

Aladdin *et al.* (2016) conducted a comparative study of var. *alata*, var. *pumila* and var. *lanceolata* using microscopic technique to identify the anatomical characteristics presents in the leaf and stem parts of the plant. Based on the anatomical investigation; anisocytic stomata, scale and capitate glandular trichomes were present in all three varieties of *L. pumila*. From the study, Aladdin *et al.* (2016) concluded that the identification of anatomical features in terms type of stomata and trichomes, outline structure of stem and leaf margin, petiole and midrib, organisation of vascular system, areolar venation, pattern of anticlinal walls, the distribution of secretory canals and cell inclusion can be used to differentiate each variety of *L. pumila*.

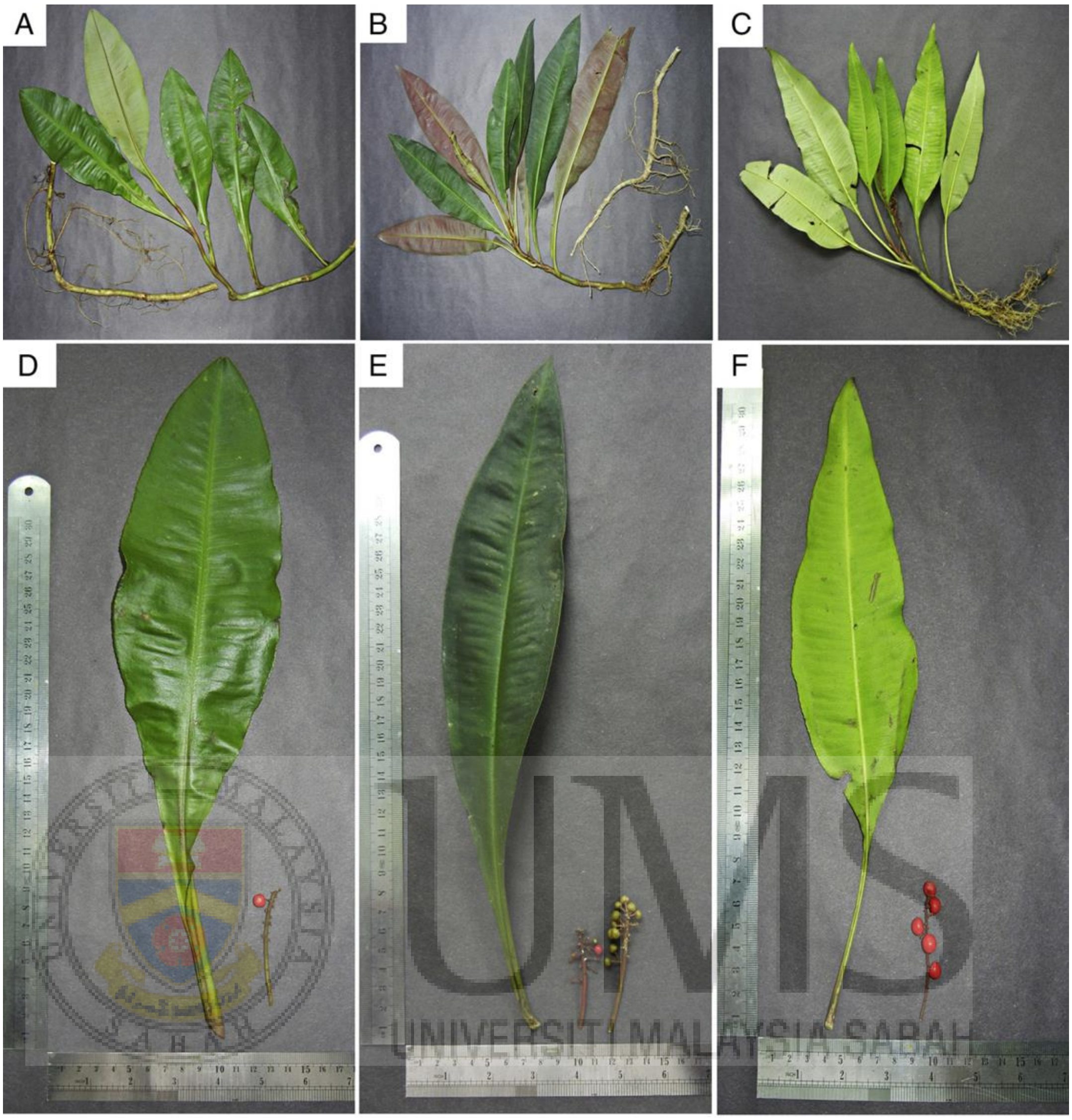

Figure 2.2: Three varieties of *L. pumila* (*ex vitro* conditions) (a) *L. pumila* var. *alata*, (b) *L. pumila* var. *pumila*, (c) *L. pumila* var. *lanceolata* and the macroscopic characteristics of leaf and fruit (d) *L. pumila* var. *alata*, (e) *L. pumila* var. *pumila*, (f) *L. pumila* var. *lanceolata*

Source : Aladdin *et al.* (2016)

2.1.3 Tissue culture of *Labisia pumila*

In the natural habitat, *L. pumila* propagates from its seeds (Mohd. Noh *et al.*, 2002). Zahari (2008) reported that *L. pumila* also can be propagated using its leaf, petiole and stem. Propagation of *L. pumila* var. *alata* high yielding clones using leaf cuttings had been conducted by Syafiqah *et al.* (2014). As *L. pumila* propagates in a slower rate in the wild (Mohd. Noh *et al.*, 2002), attempts have been made to cultivate this herb by using tissue culture techniques for the purpose of micropropagation and regeneration of healthy clones.

To date, there are only a few published studies on tissue culture of *L. pumila*. These *in vitro* studies include seeds germination and seedling development of *L. pumila* (Hartinie & Jualang, 2007), shoot regeneration (Hartinie, 2007; Ling *et al.*, 2013; Ozayanna, 2015; Shafiqah *et al.*, 2015), callus induction (Hartinie, 2007; Ling *et al.*, 2013; Ozayanna, 2015) and adventitious root induction (Hassan & Hussein, 2013; Ling *et al.*, 2013) on semi-solid medium. A recent study by Syafiqah *et al.* (2016) reported that the production of superior clone of *L. pumila* var. *alata* through tissue culture method is more feasible than using leaf cuttings for the production of future planting stocks of the herb.

2.1.4 Medicinal properties of *Labisia pumila*

Traditionally, *L. pumila* is consumed in the form of water decoction from its leaf, root or the whole plant. Between the three varieties of this herb, *L. pumila* var. *alata* is more commonly used in the Malay traditional medicine (Jamal, 2006). Indigenous Malay women drinks the water decoction in order to ease their childbirth as well as a post-partum medicine (Burkill, 1935). Other traditional usages of *L. pumila* are for treating flatulence, dysentery, dysmenorrhea and gonorrhoea, “sickness in the bones” (Burkill, 1935) and haemorrhoids (Rahman, 1998).