BIODEGRADATION CHARACTERISTICS OF Duabanga moluccana BLUME AND Endospermum diadenum (Miq.) AIRY SHAW

Hafizah Abdul Razak

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BIODEGRADATION CHARACTERISTICS OF *DUABANGA MOLUCCANA* BLUME AND *ENDOSPERMUM DIADENUM* (Miq.) AIRY SHAW

Hafizah Binti Abdul Razak

This project is submitted in partial fulfillment of the requirements for the degree of Bachelor of Science with Honours (Plant Resource Science and Management)

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Biodegradation characteristics of *Duabanga moluccana* Blume and *Endospermum diadenum* (Miq.) Airy Shaw

Hafizah Abdul Razak

Plant Resource Science and Management
Faculty of Resource Science and Technology
University of Malaysia Sarawak

ABSTRACT

Biodegradation characteristics of fast growing pioneer wood species in Malaysia are still unknown due to lack of studies on them. The purpose of this study was to determine the biodegradation characteristics of some Sarawak pioneer wood species based on weight loss through two major tests, which are the modified ASTM soil block test and Termite Resistance Test. Two fast growing pioneer species were selected namely, *Duabanga moluccana*, *Endospermum diadenum* and *Hevea brasiliensis* used as control. For soil block test, the blocks were cut into cubes of 20mm. The cubes were exposed to two test fungi namely, *Pycnoporus coccineus* and *Schizophyllum commune*, for eight week. Most of the wood weight loss exceed 10%, with *Endospermum diadenum* showed the highest weight loss among the two pioneer species, 19.64% for *Pycnoporus coccineus* and 7.06% for *Schizophyllum commune*, while *Duabanga moluccana* with 17.78% for *Pycnoporus coccineus* and 5.08% with *Schizophyllum commune*, the least between the three species. The termite resistance test was conducted according to JWPA standard and evaluated in a 3 week, no-choice laboratory tests. Cubes of 10mm x 10mm x 20mm were exposed to *Coptotermes spp.* of 150 workers and 50 soldiers in an acrylic cylinder. *Duabanga moluccana* is the most susceptible to termite attack among the two pioneer wood species with the highest weight loss at 6.33% and *Endospermum diadenum*, 4.11%, the least susceptible among the wood species. This study showed that the fast growing pioneer species wood of *Duabanga moluccana* and *Endospermum diadenum* are non-durable timber.

Key words: Biodegradation, fast growing pioneer species, *Coptotermes* sp., soil block test

ABSTRAK

Ciri-ciri biodegradasi kayu spesies perintis di Malaysia masih tidak diketahui kerana kurangnya kajian dijalankan ke atas kayu-kayu ini. Tujuan kajian ini dijalankan adalah untuk menentukan ciri biodegradasi beberapa kayu spesies perintis Sarawak berdasarkan kadar kehilangan berat melalui dua ujian, iaitu ujian ASTM blok kayu yang telah diubah suai dan ujian Ketahanan terhadap anai-anai. Dua spesies kayu perintis dipilih iaitu, *Duabanga moluccana*, *Endospermum diadenum* dan *Hevea brasiliensis* digunakan sebagai kawalan. Untuk ujian blok kayu, blok kayu dipotong kepada kiub bersaiz 20mm. Kiub tersebut didekahankan kepada dua ujian kulat iaitu *Pycnoporus coccineus* dan *Schizophyllum commune* selama lapan minggu. Kebanyakan kayu kehilangan berat melebihi 10%, *Endospermum diadenum* menunjukkan kehilangan berat yang paling tinggi di antara dua spesies kayu, 19.64% untuk *Pycnoporus coccineus* dan 7.06% untuk *Schizophyllum commune*, manakala *Duabanga moluccana* dengan 17.78% untuk *Pycnoporus coccineus* dan 5.08% untuk *Schizophyllum commune*, yang paling rendah dalam antara ketiga-tiga spesies. Ujian ketahanan terhadap anai-anai *Coptotermes* spp dijalankan berdasarkan standard JWPA dan dinilai selama tiga minggu, dalam ujian makmal tanpa pilihan. Kiub berukuran 10mm x 10mm x 20mm didekahankan kepada 150 ekor pekerja anai-anai dan 50 ekor askar anai-anai. *Duabanga moluccana* menunjukkan serangan anai-anai paling ketara dengan kadar kehilangan berat yang tinggi, 6.33% dan *Endospermum diadenum*, 4.11%, paling kurang diserang oleh anai-anai. Kajian ini menunjukkan kayu spesies perintis *Duabanga moluccana* dan *Endospermum diadenum* adalah kayu balak yang tidak tahan.

Kata Kunci: Biodgeradasi, spesies perintis, *Coptotermes* sp., ujian blok tanah
CHAPTER ONE
INTRODUCTION

1.1 General background

Malaysian forest is known for its rich tropical rainforest with variety of tree species. Tropical rainforest are a very complex community, which the shape include various size of trees (Whitmore, 1984). The tropical rainforest of Malaysia is a hub of biodiversity. Sarawak has vast forest with about 80% or almost 10 million hectares of Sarawak's total land area of 12.3 million hectares covered with forest both natural as well as secondary forests. ITTO (2002) defines secondary forests as woody vegetation regrowing on land that was largely cleared of its original forest cover. Secondary forest commonly develop naturally on land abandoned after shifting cultivation, settled agriculture, pastured or failed tree plantations. Secondary forest may also be the result of natural forest regeneration after catastrophic natural disturbances such as wildfires, storms, landslides and floods. Most tree species in secondary forest are recognized as pioneer species.

Both Duabanga moluccana Blume and Endospermum diadenum (Miq.) Airy Shaw are fast growing pioneer species. Pioneer species are plants that are well adapted to the harsh conditions of its environment, allowing them to survive in environmentally stressful conditions. For pioneer species, survival is the key of success in competing for space to live above and below the soil in the gap it occupies (Whitmore, 1984). According to Whitmore (1998), these species are highly heliophile, which are light loving or shade intolerant, in reference to their seedling requirements for solar radiation. They established themselves by taking advantage of canopy light gap opened up by tree falls. Rapid growth, a feature of these species, enables them rapidly to form new canopy suitable for more shade-tolerant species to colonize. Majority of pioneer species trees composed of families from Euphorbiaceae,
Malvaceae, Moraceae, Sterculiaceae, Tiliaceae, Ulmaceae, and Urticaceae. In Peninsular Malaysia, there are 26 species, 20 of them can be found on the road side and 18 of them grow in cluster. Meanwhile, in Borneo 44 species are recorded and most of them are similar to species found in Peninsular Malaysia (Whitmore, 1975). Therefore pioneer species has the potential to be utilized as well as source of raw material.

However the potential utilization of pioneer species depends greatly to its wood properties. Natural durability of wood is one of the properties of wood that can determine its utility. Durability of wood depends on its resistance toward biodegradation. Biodegradation can be caused by variety of causal agents, among them are, fungi, marine borers and insects. These causal agents have the capability to break down the complex polymers that make up the wood structure. Biodegradation occurs when organisms such as fungi use wood as a food source. Biodegradation of wood can be seen visually by its colour changes as well as texture as it will be soft and breakable by hand. The wood may appear stringy and has unexpected cracky pattern on its surfaces.

According to Thang (1988), there are at least 3000 species of trees recorded in Malaysia, which about 2900 species attain a diameter of 10 cm at breast height (DBH), with 890 of these species reaching harvestable sizes of at least 45 cm dbh. However there are only about 408 species have been harvested and marketed commercially according to Malaysian Grading Rules (Thang, 1988). This represent only small portion out of 3000 species of tree that are utilized commercially to reduce the pressure of cutting only certain tree species for timber which would lead to rapid depletion of forests, pioneer species can be utilized as supplement of timbers production years to come. Utilization of pioneer species would also help to preserve the primary forests by sustaining the production of both wood and non-wood
forest products. Pioneer species has the potential for the establishment forest plantation because it is fast growing and can survive harsh conditions. However little is known on the properties and characteristics of pioneer species. Complete knowledge of properties and characteristics of the pioneer species must be determined first before it can be commercialize as timber for alternative raw material of wood for several of end uses. The study of the biodegradation characteristics is important as it can show the natural durability of each pioneer species thus can promote pioneer species to be utilized as well as prolonged the in-service life of wood.

1.2 Objectives

The objectives of this study are:

a) to determine and classify the resistance of *Endospermum diadenum* and *Duabanga moluccana* to fungal decay and termite attack.

b) to compare the natural durability among the species studied.

c) to classify the damage that are derive from fungi decay and termite attack.
CHAPTER TWO
LITERATURE REVIEW

2.1 General Overview

Secondary forests refer to ecological systems deriving from clearing of natural forests for shifting cultivation. These forests have been established through a long fallow period of natural regeneration and now contain minimum crown covers of trees and are associated with wild flora, fauna and natural soil conditions. Secondary forests are established after abandonment of 10 years or more by shifting cultivators. Secondary forest formations in Sarawak are closed forests (Whitmore, 1984). Secondary forests tend to be located in accessible areas, close to human settlements, and are thus served with relatively good infrastructure. They are increasingly important component of the forest resource in the tropics and, if maintained and properly managed, may provide a wide range of goods and service at local, national and international level (Müller, 2002). Most tree species in secondary forest are recognized as pioneer species (Whitmore, 1984).

Wood is a remarkable material of great value and importance in the world economy. It is used extensively as a structural material, fuel, or industrial raw material in many parts of the world (Zabel and Morrell, 1992). In addition, wood is the basic raw material in the paper making industry, is used in textile industry and also used in the manufacture off wood composites and panel products for the building industry (Youngs, 1989). Wood production in the forest ecosystem is often associated with many other forest values and amenities such as soil development and extension of water run off, provision of superb recreational settings, reduction of atmospheric pollution, and landscape aesthetics. However wood have some
serious disadvantages that limit its usefulness for some purposes, where wood is biodegradable; combust at low kindling temperatures; dimensionally unstable at moisture content below the fiber saturation point; wood as a natural product, displays considerable variability in its appearances, chemical composition and physical properties; and has a large bulk per unit weight for fuel, pulping and chemical uses (Zabel and Morrell, 1992).

2.2 Occurrence distribution and uses of *Duabanga moluccana* and *Endospermum diadenum*

In this study, *Duabanga moluccana* and *Endospermum diadenum*, wood from different family were assessed to determine its biodegradation characteristics which are the properties of each species toward fungi and termites attack. *Duabanga Moluccana* (Sawih/Berembang bukit) derived from Sonneratiaceae family and *Endospermum diadenum* (Terbulan) from Euphorbiaceae family. *Duabanga moluccana* are widely distributed in Borneo, the Phillipines, eastern Java, the lesser Sunda Islands, Sulawesi, the Moluccas and New Guinea (Lemmens et al., 1995). According to Ashton (1988), *Duabanga moluccana* which are also medium sized tree are widespread and locally frequent on well drained but damp clay-rich fertile soils; apparently confined to habitats offering high light intensity in the young stages, especially in areas such as river banks and by dam gulleys where wind breaks or land slips have occurred, forest-edges, logged-over forests, road sides, abandoned cultivation sites and also on limestone hills. *Duabanga moluccana* is a lightweight and comparatively soft wood. Moreover this type of wood is perishable and susceptible to staining and termite attack. This is why the timber is used especially for temporary construction, furniture, boats and veneer. A decoction of the bark has been used in Indonesia for dyeing matting black (Lemmens et al., 1995).
Meanwhile for *Endospermum diadenum*, which are the second biggest family of trees in Malaysia, can be found throughout the world except in frigid regions (Whitmore, 1972); it occurs in primary forest and particularly in secondary forest on low undulating country or along streams and occasionally on permanently inundated sites, up to 1000 m altitude. It is widely distributed in Peninsular Malaysia, Peninsular Thailand, Sumatra, Borneo and intervening islands. This type of wood can be used for a variety of purposes where lightweight, comparatively soft and light-coloured hardwood is required. The wood is non-durable when used in contact with the ground where tests in Malaysia showed an average life in contact with the ground of one year. The wood is also very susceptible to termite, blue stain, pinhole borer and marine borer attack and, when sawn, to longicorn beetle attack, it is however, easy to treat with preservatives. Thus its timber is one of the favourite timbers for clogs and also used for reforestation and as shade trees, the bark is used to cure dropsy and the roots are applied to injuries (Soerianegara and Lemmens, 1994). Both of *Duabanga moluccana* and *Endospermum diadenum* were classified into light hardwoods (Malaysian Grading Rule, 1984). This category of woods are classified as non-durable for their natural durability in the tropical climate, however some species of these woods are durable in the moderate climate region.

2.3 Biodegradation of wood

Biodegradation is a subset of deterioration. It is a negative term and can be defined as any undesirable change in the properties of a nonliving material caused by the activities of living organisms the major processes involved are assimilation; mechanical damage; corrosion of metal and function impairments. There are two major type of biodegradation
which are decay and discoloration (Zabel and Morrell, 1992). According to Zabel and Morrell (1992), wood is biodegradable. If this were not the case the forests would soon be cluttered with the useless skeletons of dead trees. Unfortunately the various wood-destroying insects and fungi are unable to distinguish between forest waste and wood useful in service. Wood is now a valuable commodity and it is essential for wood to be utilized efficiently in order to conserve world resources but also to avoid unnecessary cost, both to the individual user and to importing nations as a whole. Biodegradation can be caused by variety of causal agents, among them are, fungi, marine borers and insects (Richardson, 1993). In this study, the focus is on biodegradation by fungi and termites.

Fungi live in a wide range of natural and man made habitats. They are found in terrestrial and aquatic environments and occur as parasites growing on living plants and animal tissue, or as saprophytes growing on dead organic matter. In this latter respect they have a very important role to play in the processes of natural degradation and recycling of waste materials in soil, water and compost situations (Eaton and Hale, 1993). According to Vevers (1984), fungi comprise the large order of ‘lower plants’ which includes mushrooms, moulds, rusts and yeasts. Fungi lack of chlorophyll, the catalyst or agent which enables most green plants to manufacture their own food from inorganic material by using the heat and light of sun. Fungi must therefore obtain their nourishment from dead or decaying matter. Wood decay is a common occurrence among all kinds of trees. Decay can affect the roots, sapwood, or heartwood of a tree. The results may be seen in dying trees or in trees which have smaller leaves and slower growth. Some trees may appear to be healthy, yet have extensive decay within the heartwood. These trees, although appearing healthy, are structurally weakened and will be more vulnerable to windthrow (Reeves, undated). Decays
are the major type of damage to wood in use and is essentially is the result of wood digestion by fungi (Zabel and Morrell, 1992). According to Manion (1991), methods of classifying decay types are based on the decay process and the modified appearance of the decayed wood. There are three main types of decays in wood; they are brown rot, white rot and soft rot.

A large number of basidiomycetes have been typified as brown rot fungi (Davidson et al., 1938). In the case of brown rots, the fungus destroys the cellulose, leaving the lignin which gives the wood characteristics brown coloration and usually cross grain cracking (Richardson, 1993). At late stages of decay and when dry the wood commonly shows deep cross-cracking due to shrinkage caused by loss of wood cell wall carbohydrates; it may also show longitudinal cracks (Eaton and Hale, 1993). White rot is a form of wood decay which results in bleaching of the wood (Richardson, 1993). It decomposes all cell wall components. However, they may attack the lignin, cellulose, or hemicelluloses in different orders. The white rots are further subdivided into stringy, spongy, mottled or pocket rots. Sometimes the decayed wood of white rot fungi is more yellow or yellow brow than white. But the decayed woods are rather fibrous in appearance (Manion, 1991). A third type of decay fungus, called soft rotter, is separated from the others primarily on the selective attack of only a portion of wall (Manion, 1991). According to Eaton and Hale (1993), the term soft rot was coined by Savory (1954) because it is so aptly describes the surface softening of wood attacked by lygnoiytic members of the Ascomycotina and Deuteromycotina. Soft rot occurs commonly in wood that is saturated with water or in wood that is in direct contact with soil (Manion, 1991).
According to Zabel and Morrell (1992), natural decay resistance has been evaluated by exposing wood samples to decay agents for various periods and rating the resultant degree of degradation. The resistance of timber to fungal decay can be assessed through two methods which are laboratory test and field test. Most lesser used species are known to be non-durable (Eaton and Hale, 1993), for example in a recent study on the decay resistant of *Dyera polyphylla*, a light demanding species, showed that this species is not susceptible to fungi attack (Dayang Filidia, 2004). Another study, on *Hevea brasiliensis* by Jusoh and Kamdem (2001), based on laboratory evaluation showed that this species is susceptible to fungi attack. However, studies by Amartev and Hanson (2002) showed that, *Albizia ferruginia*, a lesser used tropical hardwood species, is classified as a very durable timber and *Albizia zygia* is moderately durable based on laboratory evaluation.

Termites or white ants, as they are commonly called, are found most abundantly in tropical countries and are also widely distributed in temperate region (Creffield, 1991). Termites are most probably the most serious wood-destroying pests. They are not ants, but belong to the Isoptera whereas true ants are hymenoptera, an order which includes the bees and wasps. The termites are social insects like the true ants, living in communities with specialized forms or castes, the workers and soldiers, as well as male and reproductive individuals (Richardson, 1993). Termites are among the few insects capable of utilizing cellulose as a source of food. Since cellulose is the major constituent of most plant tissues it follows that the majority plants and plant products are likely to be susceptible to termite damage (Creffield, 1991). There are approximately 1900 identified species of termites and more than 150 are known to damage wood in buildings and other structures (Richardson, 1997). They cause damage to living trees and many crop plants, but perhaps of greatest
importance is the destruction inflicted on timber used for constructional purpose both outdoors and inside buildings (Eaton and Hale, 1993).

Termites which attack timber are usually identified as either subterranean, dampwood or drywood termites (Eaton and Hale, 1993). In this study, the focus is more on Coptotermes sp, which is a subterranean termite. Subterranean termites can be lower termites e.g Coptotermes, Mastotermes Reticulitermes, Schedorhinotermes or they can be members of the higher termite family Termitidae. They occur commonly in tropical soils especially in rainforests where they play an important part in the recycling of dead and decaying plant material (Eaton and Hale, 1993). Coptotermes sp. attack both trees and seasoned timbers. Their nests may be completely underground, in an old stump or a living tree, in sleeper retaining walls or in the form of a domed or rounded conical mound, which may rise up to three meters aboveground (Creffield, 1991). The population of a mature colony of subterranean termites will consists of three principal castes and juvenile forms. The three major castes are the reproductives, the soldiers and the workers. Coptotermes sp. are readily recognized by the soldiers which measures up to about 6 mm long with rounded, rather pear shaped yellowish heads and dark slender tapering mandibles without visible teeth. Their habit of exuding a drop of milky fluid from the fontal gland when disturbed offers a sure means of identifying them in life (Creffield, 1991). Wood attacked by subterranean termites often appears superficially intact because degradation is mostly internal (Eaton and Hale, 1993).

According to Sornnuwat et al. (1995), for the fundamental study on termite control, various laboratory methods have been presented by many researchers. The major aim of laboratory test is to give an indication of the resistance of materials or the dose of termiticide
in preventing damage to timber products and other materials in the field. Laboratory standards such as Japan Wood Preserving Association (JWPA) Standard 11 (1) – 1981, American Wood Preservers Association (AWPA) Standard M 12-1972 and European Norm (EN) 117-1989 and 118-1190 can be used to assess the natural resistance of wood to termite attack. In a study by Arango et al. (2004), tropical wood species are more resistant to *Reticulitermes flavipes* compared to some native wood species found in United States.

According to a study on resistance of selected Malaysian woods to attack by *Coptotermes formosanus* by Grace et al. (1998), showed that *Tectona grandis, Koompassia malaccensis, Kompassia excelsa* and *Causarina equisetifolia* were resistant to termite attack, meanwhile Malaysian grown Teak and *Azadirachta excelsa* demonstrated somewhat less, but still significant termite resistance; however *Acacia mangium, Albizia facaltaria, Araucaria cunninghamii, Pinus caribae* and *Pinus sylvestris* proved to be susceptible to termite attack.

A recent study on termites attack of hardwood species, *Eusideroxylon zwageri* and *Protoxylon melagangai* showed that these species were resistance to termites attack compared to *Hevea brasiliensis* and *Agathis borneensis* which are less resistance (Abang Abdul Khalid, 2004).
CHAPTER THREE
MATERIALS AND METHODS

Two main experiments were conducted. They were:

1) Soil Block Test
2) Termite Resistance Test

3.1 Soil Block Test

3.1.1 Preparation of Wood Samples

_Duabanga moluccana_ (Sawih/Berembang) and _Endospermum diadenum_ (Tebulan) of 20 to 25 years were both obtained from Sabal Forest Reserves. _Hevea brasiliensis_ (Rubberwood) of 20 to 25 years were used as control and for feeder strips which were obtained from secondary forest around University of Malaysia Sarawak (UNIMAS).

Wood samples were sawn into wood blocks of 20 mm x 20 mm x 20 mm (Figure 1) from the sapwood section. The sample blocks were mixed and randomly selected for subsequent treatment. All sample blocks were cleaned from dust and splinters prior to first weighing (W₁) to obtain moisture content at room condition. All sample blocks then underwent conditioning process and dried in oven at 60°C to constant for three to four days. Subsequently, the samples were weighed again to obtain W₂ where this is the basis for determining the weight loss caused by the decay. After conditioning, the samples were wrapped in aluminium foil and sterilized by autoclaving for 15 minutes at 121°C.
3.1.2 Preparation of Feeder Strip

*H. brasiliensis* were used as feeder strips in the decay test. The feeder strips were sawn into rectangular block measuring 3 mm x 30 mm x 35 mm.

3.1.3 Preparation of Fungi Inocula

Two species of fungi were used consist of two white rot fungi, *Schizophyllum commune* and *Pycnoporus coccineus*. Fungi strains were obtained from the division of forest Products Technology, Forest Research Institute of Malaysia (FRIM). The media used to culture the fungi was Malt Extract Agar (MEA). The preparation of this agar was based on the followings:

- MEA powder - 33.6 grams
- Distilled water - 1 litre
Malt Extract Agar powder was dissolved in distilled water thoroughly using heat. After the MEA were dissolved, the media solution was sterilized at 121°C for 15 minutes prior pouring the agar solution into petri dishes which were done in the laminar flow to prevent contamination. Each fungi species were inoculated into five petri dishes and incubate for 10 days. At the end, plugs of about 5mm² from actively growing cultures were used to inoculate all sample blocks. Constant checking was done to detect any contamination.

3.1.4 Preparation of Plastic Bags

Decay test was done in soil culture plastic bags (Figure 2). Soils were filled inside each bag until 1/3 full or at approximately 200 grams. Then all the bags, alongside feeder strips (one in each bag) were sterilized by autoclaving at 121°C for 20 minutes to kill all the microorganisms in the soil and feeder strips to prevent contamination during decay test. The feeder strips were dipped in Malt Extract to provide satisfactory growth of fungi. The plastic bags were left to cool before the decay test was done.