STUDIES ON THE DURABILITY OF *Acacia* HYBRID WOODS THROUGH ENVIRONMETAL FRIENDLY OIL-HEAT TREATMENT PROCESS

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ABSTRACT

STUDIES ON THE DURABILITY OF *Acacia* HYBRID WOODS THROUGH ENVIRONMENTAL FRIENDLY OIL-HEAT TREATMENT PROCESS

The durability of oil-heat treated *Acacia* hybrid wood, an important plantation species in Sabah, was tested using *in-vitro* techniques against three different wood decay fungi (*P. sanguineus, C. versicolor* and *G. trabeum*). To determine the effectiveness of the treatments , 900 wood blocks of *Acacia* hybrid (~1.0 x 2.5 x 2.5 cm) were soaked into boiling palm oil with different temperature range between 180°C - 220°C and period between 30 – 90 min before exposed to the fungal cultures for 12 weeks. Results from the *in-vitro* tests showed that massive colonization by fungi on woodblocks affected the weight loss of samples from top, middle and bottom portion of trees, with a range of 2.89 – 10.59%, 4.67-20.33% and 4.27-20.55% (*P.sanguineus*); 3.26-15.42%, 3.88-16.84% and 4.69-18.79% (*C.versicolor*) and 0.88-4.94%, 1.22-5.29% and 1.22-4.89% (*G. trabeum*). The percentage of moisture contents of the oil heat treated Acacia hybrid wood had decreased in relation to the treatment given (5.96%, 5.61% and 4.40%) compared to untreated samples (12.04%, 13% and 13.48%) for top, middle and bottom portion respectively. A lesser amount of weight loss indicated greater durability of woods in relation to the treatment given, subsequently implied the potential of the heat treatment in improving resistance of *Acacia* hybrid woods against wood decay fungi.

ABSTRAK

Ketahanan kayu Acacia hybrid yang diberi pemanasan minyak, yang mana Acacia hybrid merupakan spesis perladangan yang penting di Sabah, telah diuji dengan teknik in-vitro terhadap tiga fungi pereput kayu (P. sanguineus, C. versicolor dan G. trabeum) Untuk menentukan keberkesanan rawatan-rawatan, 900 blok-blok kayu Acacia hybrid (~ 1.0 x 2.5 x 2.5 cm) telah di rendam di dalam minyak kelapa sawit yang mendidih pada julat suhu antara 180°C - 220°C dan tempoh masa 30 – 60 min sebelum didedahkan kepada kultur fungi pereput kayu selama 12 minggu. Keputusan daripada ujian in-vitro menunjukkan kolonisasi yang banyak mempengaruhi kehilangan berat sampel-sampel dari bahagain atas, tengah dan bawah pokok , dengan julat 3.26-15.42%, 3.88-16.84% and 4.69-18.79% (C.versicolor) and 0.88-4.94%, 1.22-5.29% and 1.22-4.89% (G. trabeum). Peratusan kandungan air di dalam sampel Acacia hybrid yang diberi pemanasan minyak menurun sehubungan rawatan yang diberikan (5.96%, 5.61% and 4.40%) berbanding tanpa pemanasan (12.04%, 13% and 13.48%) untuk masing-masing bahagian atas, tengah dan bawah. Kehilangan berat yang rendah menunjukkan semakin meningkatnya ketahanan kayu setelah diberikan rawatan. Dan seterusnya juga menunjukkan potensi rawatan haba dalam meningkatkan ketahanan kayu Acacia hybrid terhadap fungi pereput kayu.

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prolific mycelia (arrows) permeating and filling the lumen of vessels of untreated wood (a, c & e) was observed as compared to wood experienced Treatment 9 (b, d & f). Bars represent magnification scale in µm

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CHAPTER 1

INTRODUCTION

1.1 *Acacia* sp. in Asia

Acacia is a well known tree genus in the Family: Mimosaceae and it contain more than 1200 species in tropical and subtropical regions (Simmons, 1987). Several of these species which is widely used as plantation species are *Acacia mangium* and *Acacia auriculiformis*. They were selected because of their less site selective and fast growing characteristics, besides the quality of the timber. *Acacia*s grew well in other parts of the tropical forests despite it originated from Australia (Ramatoulaye *et.al*, 2007), although Boland *et al.* (1990) reported that some species of the genus like *A. mangium* and *A. auriculiformis* are also natural in Papua New Guinea and Indonesia. The species were then introduced and hence widespread to other countries such as Vietnam, Bangladesh and also Malaysia (Le, 2001 and Latif, 1994).

Many tropical countries considered these species as an important fast growing species including the hybrid between these two species (Nguyen *et.al*, 2008b) and for that, the plantation area of these species has steadily increased over time, especially in Asia. Arif *et al.* (2004) mentioned that in Indonesia, there are more than 800,000 hectares of *A. mangium* plantation established. Similar pattern i.e extensive plantation establishment of *Acacia*s has developed in Southeast Asia, again this was encouraged by its fast growth, good form and the utilization potentials of the wood (Sabri *et al.*, 1993). Martin (2004) also informed that the tree plantations such as with this species could help reduce the greenhouse gas in addition to providing pulps and fire wood. Hence, it contributes in the mitigation of global warming through greening or increased reforestation; which will stocks more carbon and thus help keep a healthy environment.

1.2 *Acacia* sp. in Sabah

The endeavor towards enterprising the forest plantations in Sabah has begun in the 1960s, especially with the inception of Forest Plantation Section by the Forestry Department to establish trials to demonstrate the capability of selected trees especially those of fast growing species. *Acacias* was one of the genus that had been chosen following the excellent growth performance of *A. mangium*, which was first introduced from Australia and planted in Ulu Kukut as fire break buffer in 1966 (Koichi, 2003). Some other *Acacia*s were also planted including *A. auriculiformis* which was noticed to have less mortality. Conscious of these different valuable properties in both species, the breeding using the two *Acacias* was carried out to gain the best product (species) which genetically have good qualities from both parent trees; the result, a new seedlings known as *Acacia* hybrid, was obtained in Malaysia in 1972 (Nguyen *et al.*, 2008b). This 'new' species then was observed to be equally good as its parents in terms of rapid growth, wood quality and adaptation to many soil types, thus were also widely planted, as addition to *A.mangium* and *A.auriculiformis* (Le. 2001).

Currently, *Acacia* hybrid (*A.mangium* x *A.auriculiformis*) is one of the plantation species in Sabah which has higher density and straight tree shape (Toshiaki, 2008). The height and diameter of this species also more higher than its parents (Nguyen, 2008a). Latif (1994) reported that the female parent of this *Acacia* hybrid was *A.mangium* while the male parent was *A.auriculiformis.* Regarding to these properties (fast growing and straight shape), the demand for *Acacia* hybrid products such as pulpwood for domestic paper mills, raw material for manufacturing medium-density fiberboard and woodchips for the export market had increased (Martin, 2004). Plantation area of this species also developing to 55 000 hectares in sabah since 1985 and expected to increase (Udarbe and Hepburn, 1987; Yamamoto, 1998).

The economic value of this species of course relies also on its wood properties. This aspect have the subject of various studies for the *Acacia* hybrid encompassing wood durability and resistance against wood decay fungi. Kevin *et.al* (2009) reported that the durability of wood is a very vulnerable property because of many microorganisms including fungi, insects and bacteria can cause severe degradation on the wood under suitable environment conditions. So, as for any other tree species, durability of the wood could be enhanced by applying treatments on it. However some treatments especially involve the use of chemicals are hazardous and high costs. Another alternative which is widely used is heat treatment (Muss *et al.*, 2006). In Europe, several heat treatment processes have been developed in order to enhance the durability of wood (Momohara, 2003). Wang and Cooper (2005) reported that in Europe, thermal modification of wood have successfully been carried out using steam, nitrogen or oil as the heat transfer and oxygen excluding medium.

In Finland, Thermo Wood process using steams was used (Syrjänen and Kangas, 2000), whilst in France nitrogen was used in Retification process (Dirol and Guyonnet, 1993). In the Netherlands, Plato process was also used (Boonstra *et al.*, 1998; Tjeerdsma *et al.,* 1998, 2000; Militz and Tjeerdsma, 2001) and in Germany, heat treatment process by using oil (Sailer *et al.*, 2000; Rapp and Sailer, 2001) was reported. To augment high durability to wood, hydrothermolysis have also been recently assessed by Syrjanen and Kangas (2000) which aimed at stabilizes the timber as similar to the used of high temperature drying process by Shuichi *et al.*, (2005). However, that treatment process considered complicated for large scale production due to high temperature needed to get good biological durability (Saila and Pertti, 2001); however but the effect of this treatment – i.e. heat treatment - was already known which is it could increase the durability of wood.

Oil-heat treatment is one of the methods that could be carried out by using palm oil which is only need a low cost than other treatments. Another factor is that, among the vegetables oils, palm oil is high in saturated fatty acids thus it could be in semi-solid state at ambient temperature (Wand and Cooper, 2005). Due to this and therefore the heat treatment, could reduce fungus and termites resistance because of the effect of the high temperature on wood durability (Kurisaki *et al.*, 2001).

Additionally, the durability of *Acacia* hybrid wood can be assessed in three ways; service use, field trials and/or from laboratory testing (Curling, S.F. and Murphy, R.J., 1999). In this study, the focus was on laboratory testing (in-vitro test).

1.3 Objectives

The general objective of this study was to study the effectiveness of heat treatment process on the durability of *Acacia* hybrid woods against selected wood decay fungi. This was achieved through several specific objectives as below:

1. To study the durability of oil-heat treated *Acacia* hybrid woods through accelerated laboratory tests;
2. To examine changes in the physical properties of oil-heat treated *Acacia* hybrid woods; and
3. To observe changes in the microstructure of oil-heat treated *Acacia* hybrid woods through Scanning Electron Microscope.

CHAPTER 2

LITERATURE REVIEW

2.1 *Acacia* hybrid

The *Acacia* hybrid is a cross breed between *A. mangium* and *A. auriculiformis* (Chiai, 1993; Nguyen *et al.*, 2008). Both of these parental species are natural to Australia - *A. mangium* mainly in Queensland whilst *A. auriculiformis* in Darwin (Lee *et al.*, 1993). *Acacia* hybrid, which inherit the genetic traits of fast growing (from *A. mangium*) and straighter shape (from *A. auriculiformis*) was considered to have a promising potential for plantation use since it has been noted to be more vigorous and adaptable to various soil types (Chiai, 1993; Pinyopusarerk, 1993; Nguyen *et al.*, 2008). This has made it as one of a major fast growing species in a many regions such as Australia, Malaysia, and Thailand (Yoshiyuki *et al.*, 2002). Additionally, another important characteristic is that *Acacia* hybrid was reported to be less susceptible to disease than its parental species (Nguyen *et al.*, 2008). This quality has stimulate the establishment of *Acacia* hybrid planting in Malaysia, particularly Sabah.

In Sabah, biclonal orchards for mass production of the seeds of *Acacia* hybrid were established and more than 55,000 hectares had been planted (Jiwarawat *et al.,* 1996). Vietnam had also taken similar initiative where *Acacia* hybrid had been chosen as one of the forest tree species. In 2001, a total of 2.6 million hectares was planted (Martin, 2004). A huge plantation of a species would certainly attract various studies.

Bueren (2004) reported that *Acacia* hybrid had almost double in terms of growth rate as compared to its parental species (*A. mangium* and *A. auriculiformis*). At the same time, despite the vigorous growth increment, the wood quality is good for pulping as well as for particleboards and medium density fiberboard production (Nguyen, 2002; Nguyen, 2004). Being harvestable at a shorter rotation and with significant yields higher than their parental species, has make *Acacia* hybrid a species of high demand in the market (Nguyen *et al.*, 2009).

2.2 Durability

European Standard (EN350-1) has defined the natural durability of wood as an inherent resistance against wood destroying organisms (Acker *et al.*, 2003). Bailleres and Durand (2000) added that the natural durability may vary enormously whether between trees or within the same tree individuals.

Table 2.1: Natural durability classes for temperate and tropical exposure and laboratory exposure

Durability Class	Service life under		
	Temperate conditions (years)	Tropical conditions (years)[b]	Laboratory conditions (% weight loss)[a]
Perishable	< 5	< 2[b]	> 30
Non-durable	5 – 10	2 – 5[b]	10 – 30
Moderately durable	10 – 15	Not given	5 – 10
Durable	15 – 25	5 – 10	1 – 5
Very durable	25 +	10 +	< 1

[a] 16 weeks incubation at 22°C test fungi listed in Table 2.2

[b] In some tropical countries the term perishable is not used and non-durable is used to describe this class; in this case moderately durable is used to describe 2-5 years service life.

Source: (Findlay, 1966)

Natural durability of wood was also categorized in relation to the environmental conditions that they were in for example temperate, tropical or *in vitro* (Table 2.1). Such categories however was only applied to basidiomycete decay fungi such as brown and white rot (Table 2.2) under high decay risk, and may not apply to other situation or biodeterioagens (Eaton & Hale, 1993).

Table 2.2: Test fungi used in natural durability tests by BRE, UK

Serpula lacrymans	*Gloeophyllum trabeum*
Coniophora puteana	*Trametes (Coriolus) versicolor*
Antrodia (Fibroporia) vailantii	*Pycnoporus (Polystictis) sanguineus*

Kokutse (2006) asserted that durability of wood was depending on several factors such as genetic of the origin tree, silvicultural prescription, climate and environmental conditions. However, the durability of wood against decay fungi (*eg.* In Table 2.2) could be increased through heat treatment as during the process chemical properties of wood and other components like carbohydrate could be transformed and changed (Baechler, 1959; Highley, 1970). However, a decline of decay durability is also possible due to the likely generation of low molecular weight sugar fragments from the hydrothermal changes of hemicelluloses during the drying process including the steam treatment, although a different result were obtained between different fungi (Sehlstedt, 1995).

2.3 Heat Treatment

Woods, for the purpose of extending its durability, can be treated in various ways and one of them is 'heat treatment'. In Finland, for example, eight heat treatment plants were established to deal with a production of around 35,000 m^3 per year (at least in 2000). These treatment plants did not use chemical but put a high pressure to replace the heat and water vapor in the wood (Tuula and Kestopuu, 2001). It is an environmental friendly treatment which is not hazardous to both people and the environment. Some countries used pesticides (*eg.* In Table 2.3) for preservation of wood. In certain regions such as Japan, Australia, USA and Southern EU, have given due attention to termite durability as well as decay durability when heat treated wood materials are used for building and exterior construction (Shuichi *et al.*, 2005).

Different heat treatments need different range of temperature. Tjeerdsma *et al.* (1998) reported that suitable temperature for Plato process ranged between 160°C to 190°C while for Ratification process and Bios procedure needs a temperature range between 200°C to 240 °C (Kamdem *et al.*, 2002). Rapp and Sailer (2000) suggested that temperature range for oil-heat treatment is between 180°C to 220°C.

According to Weiland & Guyomet (2003), heat treatment at a very high temperature (over 150°C) should be an effective method as an alternative to improve the durability of wood. Reinprecht (1999) suggested that high temperature rendered the wood a high resistance to fungi and thus a range from 150°C and 240°C can be used. Conversely, duration of treatment is also important. Saila and Pertti (2001) reckoned that the properties of heat treated wood are depending on temperature and duration of which the former has the greater effect on many properties than the later.

Many reports had appeared on the evaluation of the effect of high temperature on wood properties (Kubojima *et al.*, 2002). However, the methods of using high temperature on wood become the subject and arguments of many studies as wood be dried upon extreme heating. But the European process suggested that high temperature wood drying process could increase wood durability if the process keeps wood at a high temperature enough (Momohara *et al.*, 2003).

Table 2.3: Restricted use pesticides

Pesticide	Advantages	Disadvantages	Toxic effects		Special Precautions	Limits on use
			Acute	Chronic		
Creosote	1. Toxic to fungi, insects and marine borers 2. Insoluble in water 3. Ease of handling and application	1. Dark color 2. Strong odor 3. Leaves oily, unpaintable surface 4. Tendency to bleed or exude from wood surface 5. Can's be used in homes or other living areas because of toxic fumes	1. Skin irritation, burns or dermatitis 2. Vapors irritating to eyes and respiratory tract 3. Ingestion can cause nausea and abdominal distress	1. Laboratory animal studies indicate that it is a carcinogen (cancer causing agent) 2. Has been associated with skin cancer in some occupationally exposed workers 3. Bacteria and laboratory animal studies indicate that it is a mutagen (cause gene defects)		1. Can't be applied indoors, nor can it be used where it may contaminate food, feed, drinking water or irrigation water 2. Can't be applied to wood intended for use in interiors, except for those support structures that are in contact with the soil in barns, stables and similar sites and that are subject to decay or insect infestation

Source: Thomason *et al.* (1998)