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Effectiveness of Hot Oil Treatment on Cultivated 15 Year-Old *Acacia* Hybrid Against *Coriolus versicolors, Gloeophyllum trabeum* and *Pycnoporus sanguineus*

(Keberkesanan Rawatan Minyak Panas Terhadap *Acacia* hibrid Ladang Berumur 15 Tahun Didedahkan Pada *Coriolus versicolors*, *Gloeophyllum trabeum* dan *Pycnoporus sanguineus*)

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ABSTRACT

The effectiveness of the hot oil treatment process on 15 year old cultivated Acacia *hybrid was studied. Accelerated laboratory durability studies were conducted on the hot oil treated* Acacia *hybrid inoculated with fungi* Coriolus versicolors, Gloeophyllum trabeum *and* Pycnoporus sanguineus. *The logs of* Acacia *hybrid were harvested, segregated into bottom, middle and top portions, and later were oil-heat treated in an organic palm oil at temperatures of 180, 200 and 220°C for the duration of 30, 60 and 90 min. The wood samples that were dried and ground into sawdust was air-dried again before undergoing accelerated laboratory durability tests. Untreated samples were used as control. The durability of the wood increases with an increase in temperature and duration of the treatment. The hot oil treated samples could reduce the attack of* G. trabeum *from 20.89%, 20.94% and 21.29% in the control samples to 0.88-4.07%, 1.22-4.84% and 1.28-4.22% at bottom, middle and top portions, respectively. The attack of* C. versicolors *were reduced from 26.59%, 30.28% and 34.79% in the control samples to 2.89-9.41%, 3.88-16.84 and 4.27-17.34% at bottom, middle and top portions. However, the attacked of* P. sanguineus *were least effective with 31.42%, 36.33% and 36.55% in control samples to 3.26-12.55%, 4.67-15.36% and 4.69-19.22% at bottom, middle and top portions. Massive colonization of mycelia occurs in vessels of the untreated* Acacia *hybrid wood in comparison to the hot oil treated wood when observed through scanning electron microscope.*

Keywords: Cultivated Acacia *hybrid; durability; fungi inoculation; hot oil treatment; scanning electron microscope*

ABSTRAK

Keberkesanan proses rawatan minyak panas terhadap hibrid Acacia *ladang berumur 15 tahun dikaji. Kajian ketahanan cepat makmal telah dijalankan ke atas hibrid* Acacia *ini melalui inokulasi kulat* Coriolus versicolors, Gloeophyllum trabeum *dan* Pycnoporus sanguineus. *Kayu hibrid* Acacia *yang dituai, diasingkan mengikut bahagian pangkal, tengah dan atas, dan kemudian dirawat dengan minyak panas organik kelapa sawit pada suhu 180°C, 200°C dan 220°C bagi tempoh 30 tahun, 60 dan 90 min. Kayu ini kemudiannya dikering, dikisar menjadi serbuk dan dikering udara sekali lagi sebelum menjalani ujian ketahanan cepat makmal. Kayu tanpa rawatan digunakan sebagai kawalan. Ketahanan kayu yang dirawat ini didapati meningkat ketahanannya dengan peningkatan suhu dan tempoh rawatan. Rawatan minyak panas ini dapat mengurangkan serangan* G. trabeum *daripada 20.89%, 20.94% dan 21.29% dalam kayu kawalan kepada 0.88-4.07%, 1.22-4.84% dan 1.28-4.22% di bahagian bawah, bahagian tengah dan atas kayu hibrid* Acacia. *Serangan* C. versicolor *dapat dikurangkan daripada 26.59%, 30.28% dan 34.79% kepada 2.89-9.41%, 3.88-16.84% dan 4.27-17.34% di bahagian bawah, tengah dan atas kayu. Walau bagaimanapun, kayu yang diserang* P. sanguineus *kurang berkesan dengan 31.42%, 36.33% dan 36.55% kepada 3.26-12.55%, 4.67-15.36% dan 4.69-19.22% di bahagian bawah, bahagian tengah dan atas. Pembiakan secara besar-besaran mycelia kulat berlaku kepada kayu hibrid* Acacia *yang tidak dirawat berbanding dengan kayu yang mendapat rawatan minyak panas apabila diperhatikan melalui mikroskop elektron imbasan.*

Kata kunci: hibrid Acacia *ladang; rawatan minyak panas; inokulasi kulat; ketahanan; mikroskop elektron imbasan*

INTRODUCTION

Acacia species are among the most popular species in the agro-forestry industry in Malaysia. *Acacia* species such as *Acacia mangium, A. auriculiformis* and *Acacia* hybrid are major fast growing plantation species not only for timber production, but also for greening purposes in the tropical region (Hamami et al. 1989; Semsuntud et al. 1991; Yamamoto et al. 2003). The properties of the plantation species seem to vary much more than that of naturally grown species. Studies have shown that most planted species such as *Acacia* is slightly durable, especially when they are placed in exposed condition and in ground contact uses. The uses of preservatives are necessary in order to prolong the service life span of the wood products for certain periods of time (Izyan et al. 2010; Eaton & Hale 1993). However, wood treatment used preservative are considered to be non eco-friendly as they mostly have heavy metals and discharge toxin to the environment.

Increased in the environmental awareness by the general public, combined with an increasingly stringent legislature in recent years has led to greater restrictions in the use and disposal of many of the conventional preservatives, which support the use of renewable resources and environment friendly chemicals have resulted in high interest in "non-biocidal" preservatives (Berard et al. 2006). Efforts have been intensified to develop environmental friendly wood preservatives. One of the new environmentally friendly techniques used in enhancing the durability of wood is the heat treatment process. Heat treatment seems to be a suitable treatment for woods because of its advantage to being non toxic and does not require chemical application.

An alternative method in treating timber by mean of the heat treatment process has been studied by several researchers (Leithoff 2001; Razak et al. 2004a, 2004b & 2005). The initial findings indicated that this method is effective in enhancing the timber durability against insects and fungi biodegradation. However, the effectiveness of this process is largely depending on the system used and type of oil that is to be used as the heating medium. Oil with the high boiling point is normally preferred. Studies on the heat treatment process using diesel and palm oil as heating medium have been carried out by Razak et al. (2004a, 2005). The diesel heat-treated bamboo was found to be effective for an indoor usage.

The objective of this study was to investigate the effect of oil heat treatment process on the durability of 15 year old *Acacia* Hybrid. This was achieved by inoculating the oil treated *Acacia* hybrid with fungi *Coriolus versicolors, Gloeophyllum trabeum* and *Pycnoporus sanguineus* and assessing their durability in an accelerated laboratory durability tests

Materials and Methods

MATERIALS

Three defects free logs of 15 year-old *Acacia* hybrid trees were harvested from a forest plantation at Sabah Forest Development Authority (SAFODA), in Kinarut, Kota Kinabalu, Sabah. The trees were selected based on their straight bole, decay-free and having a minimum number of branches. The diameters of the trees at breast height were 25 to 30 cm. Wood blocks of 60 cm in length were cut from the bottom, middle and top portions of each tree corresponding respectively to 50, 30 and 20% of the merchantable height. Merchantable height is referred to the lowest point on the main stem above the stump, where utilization of the stem is limited by branching. The wood blocks were then transported to University Malaysia Sabah for further processing and subsequent testing.

SAMPLE PREPARATION

The wood blocks were air dried at room temperature for about 2 months to eliminate and neutralize stresses in them. After drying, the wood blocks were split in the middle and planed to a size of 300 mm × 100 mm × 25 mm (length × width × thickness) with a table saw. These samples contained both the sapwood and heartwood. The samples were then placed in a conditioning chamber at 20±5ºC and 65±5% relative humidity to stabilize the moisture content to 12% prior to the treatment. Once the moisture content stabilized, the samples were taken out and then underwent the heat treatment process using oil as the heating medium. Untreated samples were used as control for comparison purposes.

HOT OIL TREATMENT

This treatment was performed in a locally designed heat treatment machine containing a stainless steel tank, equipped with the thermocouples and heat generator. The tank size used in this study was 76 × 40 × 32 cm^3 (length × width × height) and 3 mm thickness. The heat in the tank was generated through an electricity power source. The heat and the duration of the treatment process were controlled by a control panel located outside the machine. Three replicates were used for each treatment condition of temperature and duration. Before the treatment, samples were stabilized at 65% relative humidity and the moisture content of the wood samples at respective conditions. Eighty-one samples were prepared prior to the treatment. Coding was made by using a marker pen on each surface of the samples. The weight of the samples was taken before and after the treatment to determine the weight loss caused by the treatment. Crude cooking oil which is palm oil was used as heating medium. This oil was chosen because it is chemically free and has a high boiling point of 320°C (Izyan et al. 2010; Rafidah 2009). The tank was filled in with oil until it reached three quarters full. Treatment temperature at 180°C, 200°C and 220°C were applied at duration of 30, 60 and 90 min. The samples were inserted in hot oil at 80°C and real treatment time started when the oil bath reach target temperature. The temperatures were recorded every 10 min, respectively. After each treatment period, the samples were removed out from the tank. The samples were then wiped with the clean cloth to avoid excessive oil from absorbing into the wood tissues. The samples were cooled down. Samples were then conditioned in a conditioning chamber at 20º±5ºC and 65±5% relative humidity. Specimens of required sizes from the treated samples were cut and tested accordance to the standard procedures.

BASIDIOMYCETE TEST

The tests were conducted based on agar-block techniques outlines by Eaton and Hale (1993). The technique was similar, in principle to the current European Standard EN 113 (BS 6009: 1982) of wood preservatives on a determination of the toxic values against wood-destroying fungi cultured on an agar medium. The *Acacia* hybrid wood used for weight loss was oven dried in 105± 5°C for 24 h to obtain the initial oven dry weight, while blocks used for microscopy was air dried. After reading the initial oven dried samples were allowed to condition in the laboratory for 2 h before being placed in conditioning room for one week at 20°C and 65% RH, respectively. The blocks were then sealed in polythene and sterilized by gamma irradiation in Co60 source at a dose of 2.5M rad. Three species of wood rotting Basidiomycetes were used in the decay tests. These were the *P. sanguineus, C. versicolors* and *G. trabeum*.

Malt extract agar of 4% concentration was used as the medium in the basidiomycete tests. The agar was autoclaved at 15 psi for 30 min and placed into sterilized plastic Petri dishes under UV light and left overnight. Each petri dish contained approximately 25 mL agar medium. Cultured fungi were then introduced into the petri dishes and left to grow for 7 days. After that sterilized plastic mesh was placed on top of the growing fungi before the sample blocks were introduced into the petri dishes and sealed. Two blocks from the same treatment were placed in every petri dish. The dishes were then kept in the incubation room at 22°C for a period of 12 weeks. After incubation the blocks surfaces were cleaned of mycelium using a clean brush, weighed, oven dried at 105°C±5°C for 24 h and weighed again to enable weight losses due to decay to be calculated.

The wood samples of oil-heat treated and untreated *Acacia* hybrid were then cut into small sizes of 0.3 × 0.3 × 0.3 cm^3 for Scanning Electron Microscopy (SEM) observation. The structure of these samples was analyzed under SEM for hyphal colonization of the woods, especially in the vessels. Preparations for the SEM analysis were made in accordance with the techniques outlines by Othman (1993) and Razak (1998). This study was conducted from October 2007 to February 2010 in UMS.

RESULTS AND DISCUSSION

The results on the study of hot oil treated *Acacia* hybrid wood treated at 180°C, 200°C and 220°C with duration of 30, 60 and 90 min, respectively are shown in Table 1. The overall results of the studies indicate success in the usage of the hot oil treatment process in reducing the attacks of the *P. sanguineus, C. versicolors* and *G. trabeum* on the tested wood samples. The rate of the fungi attack decreases as the temperature and duration of treatment increases.

P. sanguineus clearly caused the highest weight loss (31.42-36.55%) to the tested *Acacia* hybrid wood followed by the *C. versicolors* (26.59-34.79%) and *G. trabeum* (20.89-21.29%) in the control untreated samples. The bottom portions of the *Acacia* hybrid wood shows higher resistance to the attacks of the fungi in comparison to the middle and top portions. This can be expected as these woods were more dense and having higher basic density values compared to the other portions of the woods.

However, wood of *Acacia* hybrid that were treated in the hot oil proved to effective in controlling the attacked of the fungi. However, the effectiveness is dependent on the temperatures and duration of treatment applied. The hot oil treatment process proved to be effective in controlling the attacked of fungi *G. trabeum* fungi on the *Acacia* hybrid wood. The hot oil treated samples were able reduce the attacked of *G. trabeum* from 20.89%, 20.94% and 21.29% in the control samples of the *Acacia* hybrid to 0.88-4.07%, 1.22-4.84% and 1.28-4.22% at bottom, middle and top portions of the wood respectively. The attacked of *C. versicolor* were reduced from 26.59%, 30.28% and 34.79% in the control samples to 2.89-9.41%, 3.88-16.84 and 4.27-17.34% at bottom, middle and top portions. However, the attacked of *P. sanguineus* were least effective with 31.42%, 36.33% and 36.55% in control samples to 3.26-12.55%, 4.67-15.36% and 4.69-19.22% at bottom, middle and top portions of the *Acacia* hybrid.

The hot oil treatment process proved to as effective as in the uses of chemical preservatives in enhancing the durability of wood. Razak et al. (2004a, 2004b, 2005, 2007) in their investigation on the durability of oil heat treatment of bamboo *Gigantochloa scortechinii* also obtained similar result as those wood treated in hot oil treatment. process. The uses of chemical preservatives on selected bamboo species also observed the same trends (Othman 1993; Razak 1998).

Research by Stephen et al. (2003) on the production of wood decay after 12-week exposures by the ascomycetous fungi showed the percentage on weight loss of *Fagus sylvatica* and *Pinus sylvestris* against *P. sanguineus* were 34.9% and 19.1% while against *G. trabeum* were 41.4% and 54.8%. Studies on the pattern of decay caused by *P. sanguineus* in Poplar wood (Maria et al. 2004) after 10 weeks exposed to the fungus, the weight loss of Poplar wood was 51.85% and 59.05% after 150-day exposures. Report by Carol and Vina (2007) also showed the same pattern of result where the percentage of weight loss of untreated Southern *pine* against *G. trabeum* and *C. versicolors* after 12-week exposures were 40% and 25% in comparison to treated samples 36 and 15% of weight loss.

The colour and chemical properties of hot oil treated *Acacia* hybrid changed during the treatment process. Changes in the colour and chemical contents of *Acaia* hybrid were significantly affected by temperature and treatment time. The colour of the sapwood and heartwood of *Acacia* hybrid became darker once they were exposed to high temperature and longer treatment time in the hot oil thermal modification process (Razak et al. 2011a). The degree of changes varied between both wood types. The sapwood tended to darken more than the heartwood. The increment in colour of both woods increased with temperature and treatment time. The changes in the wood could be monitored in order to get the desired colour. The hot oil thermal modification process caused some changes

Table 1. Mean weight loss (%) of *Acacia* hybrid wood blocks for top, middle and bottom portion following 12 weeks exposure to cultures of *P. sanguineus*, *C. versicolors* and *G. trabeum*

Treatment	*Pycnoporus Sanguineus*	*Coriolus versicolors*	*Gloeophyllum trabeum*
Bottom Portion			
Control samples	31.42 (6.81)	26.59 (2.32)	20.89 (0.47)
T1 (180°C/30 min)	12.55 (7.69)	9.41 (1.60)	4.07 (0.49)
T2 (180°C/60 min)	9.70 (2.36)	9.14 (2.21)	3.22 (0.93)
T3 (180°C/90 min)	9.12 (2.50)	7.96 (0.69)	2.77 (1.62)
T4 (200°C/30 min)	8.78 (3.48)	7.02 (3.41)	2.24 (0.70)
T5 (200°C/60 min)	8.31 (4.56)	6.79 (1.55)	1.97 (0.94)
T6 (200°C/90 min)	7.58 (3.18)	6.74 (2.35)	1.87 (0.72)
T7 (220°C/30 min)	6.89 (5.73)	6.65 (4.63)	1.37 (1.35)
T8 (220°C/60 min)	6.16 (3.97)	5.11 (1.60)	0.99 (0.17)
T9 (220°C/90 min)	3.26 (1.65)	2.89 (1.84)	0.88 (0.42)
Middle Portion			
Control samples	36.33 (4.60)	30.28 (3.25)	20.94 (0.10)
T1 (180°C/30 min)	15.36 (7.36)	16.84 (3.07)	4.84 (3.75)
T2 (180°C/60 min)	15.24 (8.59)	12.21 (7.20)	3.84 (2.18)
T3 (180°C/90 min)	12.51 (2.96)	12.05 (4.32)	3.64 (1.02)
T4 (200°C/30 min)	11.63 (4.35)	10.86 (6.85)	3.38 (0.46)
T5 (200°C/60 min)	9.23 (6.61)	8.44 (3.69)	3.01 (0.47)
T6 (200°C/90 min)	8.88 (3.31)	7.32 (4.92)	2.48 (1.30)
T7 (220°C/30 min)	8.74 (2.87)	7.01 (3.58)	1.72 (1.06)
T8 (220°C/60 min)	6.40 (3.00)	6.31 (2.24)	1.63 (0.39)
T9 (220°C/90 min)	4.67 (2.54)	3.88 (0.72)	1.22 (0.45)
Top Portion			
Control samples	36.55 (4.67)	34.79 (3.71)	21.29 (0.56)
T1 (180°C/30 min)	19.22 (7.05)	17.34 (2.70)	4.22 (1.67)
T2 (180°C/60 min)	18.55 (4.13)	16.39 (6.83)	3.98 (1.42)
T3 (180°C/90 min)	15.80 (8.57)	15.26 (3.64)	3.97 (3.13)
T4 (200°C/30 min)	15.01 (2.26)	14.46 (4.92)	3.48 (1.04)
T5 (200°C/60 min)	15.00 (2.95)	11.23 (4.39)	3.45 (1.21)
T6 (200°C/90 min)	13.67 (2.07)	10.64 (7.83)	2.70 (0.73)
T7 (220°C/30 min)	9.81 (6.83)	9.34 (1.36)	2.51 (1.71)
T8 (220°C/60 min)	6.74 (2.09)	6.38 (4.32)	2.02 (0.72)
T9 (220°C/90 min)	4.69 (2.42)	4.27 (2.49)	1.28 (0.43)

Note: Numbers in parentheses represent standard deviation.

T1=Treatment at 180°C for 30 min., T2=Treatment at 180°C for 60 min.,T3=Treatment at 180°C for 90 min., T4=Treatment at 200°C for 30 min., T5=Treatment at 200°C for 60 min., T6=Treatment at 200°C for 90 min., T7=Treatment at 220°C for 30 min., T8=Treatment at 220°C for 60 min., T9=Treatment at 220°C for 90 min.

in the chemical compositions of *Acacia* hybrid wood. Changes in chemical components occurred with decreases in holocellulose and cellulose contents, and increases in hemicellulose and lignin contents when the *Acacia* woods were exposed to oil-heat treatment process at temperatures higher than 180°C (Razak et al. 2011b).

The use of the oil heat treatment process proved to be effective in enhancing the durability of the treated wood as in the use of chemical preservatives (Razak et al. 2011a; Razak et al. 2011b). Furthermore, this technique is considered an eco-friendly to the environment. The analysis of variance on the hot oil treated 15 year-old *Acacia* hybrid inoculated with *P. sanguineus, C. versicolors* and *G. trabeum* is shown in Table 2. The analysis shows significant differences at 95% probability for all source of variation used in the study such as the treatment at various grouping and portion of the oil palm fronds and the three type of fungi used in the study. The weight loss differences among all test blocks of *Acacia* hybrid were found to be significant and showing that the treatment, fungi and portion are each a factor to the variation. Interactions between these factors (Fungi × Treatment; Fungi × Portion and Treatment × Portion) were also found to be significant.

Figures 1 to 6 show the photo-micrographs taken by the scanning electron microscope on the hot oil heat treated *Acacia* hybrid after undergoing a 12 weeks of fungi exposure in accelerated laboratory tests. Figure 1 shows a freshly treated *Acacia* hybrid immediately after undergoing hot oil treatment process at 200°C for 60 min. The structure of the wood does not show any differences from that of the control untreated samples. Figure 2 shows a control untreated wood after a 12 weeks exposed to fungi *G. trabeum*. Fungal hypes can be seen in most part of wood especially in the vessels. Figure 3 shows a control untreated wood after being exposed to the fungi *P. sanguineus*. Massive hypae colonization can been seen in most of the cells especially in the vessel areas. Figure 4 shows a wood treated at 180°C for 60 min exposed to *G. trabeum*. Colonization of hypae can be seen but at much reduce rate compared to those in the untreated control samples. Figure 5 shows wood treated at 180°C for 60 min exposed to fungi *P. sanguineus*. The number

TABLE 2. Analysis of variance of the 15 year-old *A.* hybrid inoculated with decaying fungi for 12 weeks

Source	Sum of Squares	df	Mean Square	F	Sig.
Treatment	2171.898	9	241.322	17.759	*
Fungi	7091.639	2	3545.819	260.942	*
Portion	1239.015	2	619.508	45.590	*
Treatment × Fungi	939.122	18	52.173	3.840	*
Treatment × Portion	1182.153	18	65.675	4.833	*
Fungi × Portion	570.332	4	142.583	10.493	*
Treatment × Fungi × Portion	1630.697	36	45.297	3.333	*

Note:
* Significant at 95%,
Treatment = temperature and duration applied during the hot oil treatment process,
Fungi = type of fungi used in the study such as of *P. sanguineus*, *C. versicolors* and *G. trabeum*,
Portion= portions of the oil palm fronds used such as bottom, middle and top.

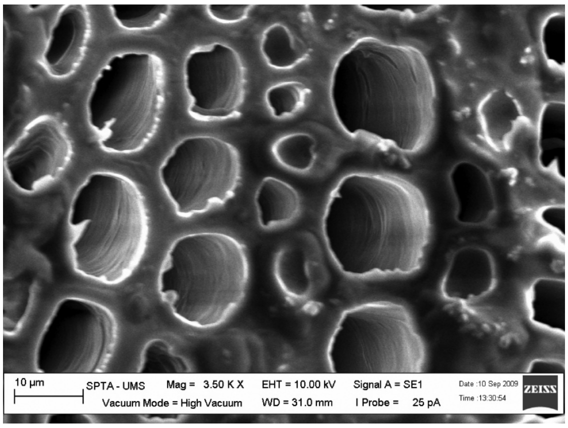

FIGURE 1. Freshly treated sample at 200°C for 60 min. The structure of the wood does not shows any differences from that of the control untreated samples

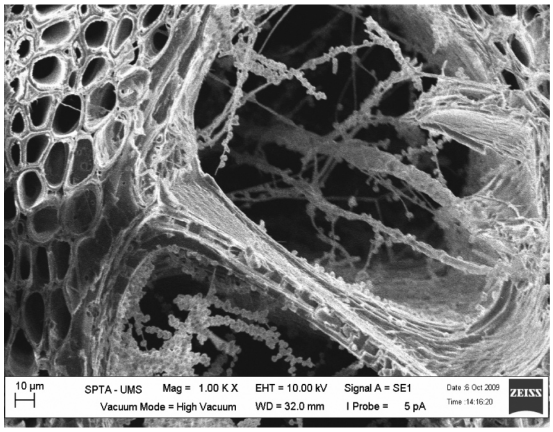

FIGURE 2. Control untreated wood exposed to *Gloeophyllum trabeum*. Fungal hypes can be seen in most part of wood especially in the vessels

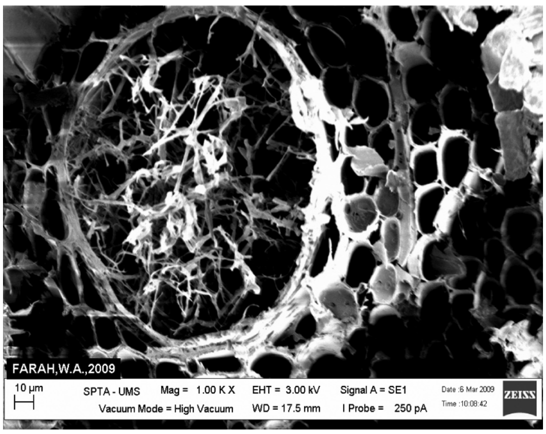

FIGURE 3. Control untreated wood exposed to *Pycnoporus sanguineus*. Massive hypae colonization can been seen in most of the cells especially in the vessel

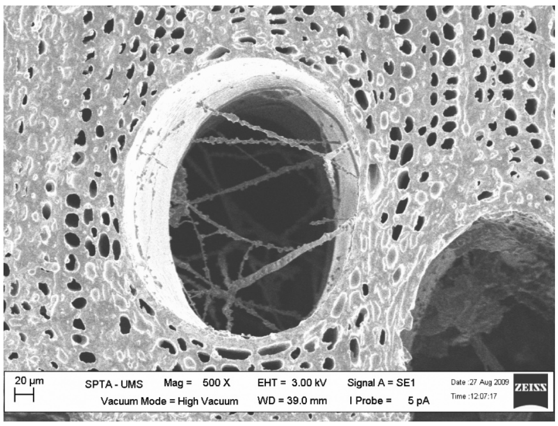

FIGURE 4. Sample treated at 180°C for 60 min exposed to *Gloeophyllum trabeum*. Colonization of hypae can be seen but at much reduce rate compared to those in the untreated control samples

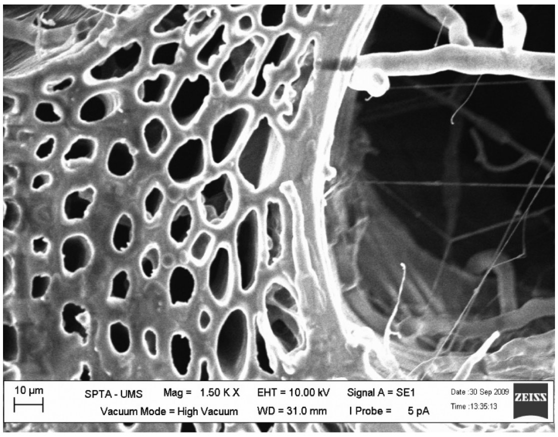

FIGURE 5. Sample treated at 180°C for 60 min exposed to *Pycnoporus sanguineus*. The number of hypae colonization is reduced

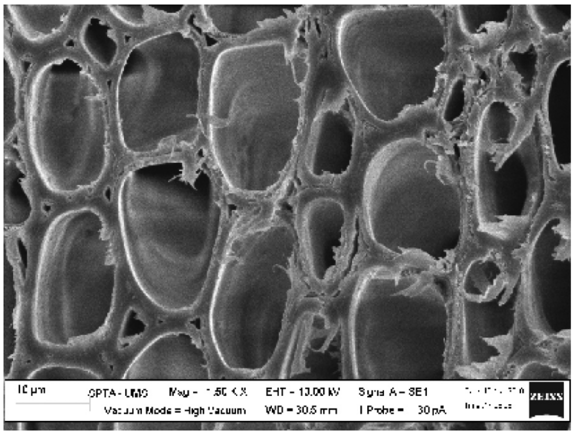

FIGURE 6. Sample treated at 220°C for 60 min exposed to *Coriolus versicolor*. No hypae are seen, but wood cells show some sign on brittleness

of hypae colonization is reduced compare to the untreated wood. Figure 6 shows a treated wood at 220°C for 60 min exposed to *C. versicolors*. No hypae are seen, but the wood cells showed some sign on brittleness.

CONCLUSION

The durability of *Acacia* hybrid woods were found to be influenced by applied temperature and duration during the oil-heat treatment process. The levels of effectiveness in the durability of the oil heat wood samples differ at different temperature and treatment duration. The percentage of weight loss decreases as temperature and duration increases.

Hot oil treatment applied at a temperature of 200°C and 220°C were found to be effective in reducing the attacked of fungi *G. trabeum, P. sanguineus* and *C. versicolors*. The structure of the wood at these temperatures do not change much in comparison to the control samples. However, treatment at 200°C for duration of 60 min is recommended for wood as it does not affect much in the colour changed in the wood.

The hot oil treated samples could reduce the attack of *G. trabeum* from 20.89%, 20.94% and 21.29% in the control samples to 0.88-4.07%, 1.22-4.84% and 1.28-4.22% at bottom, middle and top portions, respectively. The attack of *C. versicolors* was reduced from 26.59%, 30.28% and 34.79% in the control samples to 2.89-9.41%, 3.88-16.84 and 4.27-17.34% at bottom, middle and top portions. However, the attack of *P. sanguineus* was least effective with 31.42%, 36.33% and 36.55% in control samples to 3.26-12.55%, 4.67-15.36% and 4.69-19.22% at bottom, middle and top portions.

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