PROPERTIES OF PARTICLEBOARD MADE FROM TREATED OIL PALM TRUNK PARTICLES

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by

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LIST OF ABBREVIATIONS

NaOH	sodium hydroxide
CCA	chromate copper arsenate
SEM	scanning electron microscopy
MOE	modulus of elasticity
MOR	modulus of rupture
TG	thermogravimetric
DTG	derivative thermogravimetric
WA	water absorption
TS	thickness swelling
FTIR	fourier transform infrared
TGA	thermogravimetric analysis
IB	internal bonding
OPT	oil palm trunk
UF	urea formaldehyde
LVL	laminated veneer lumber
EFB	empty fruit bunch

SIFAT-SIFAT BOD PARTIKEL YANG DIHASILKAN DARIPADA PARTIKEL BATANG KELAPA SAWIT YANG TERAWAT

ABSTRAK

Kajian ini telah dijalankan untuk mengkaji kesan-kesan pra-rawatan partikel ke atas sifat-sifat bod partikel yang dihasilkan daripada batang kelapa sawit dengan menilai sifat-sifat fizikal, mekanikal, dan ketahanan biologi. Sembilan jenis bod partikel daripada batang kelapa sawit yang dihasilkan daripada pra-rawatan yang berlainan (tidak terawat, air panas, NaOH) dengan kadar penambahan bahan pengawet yang berlainan (0.06% dan 0.1%) dengan ketumpatan 0.65 g/cm^3, dimampatkan pada suhu 150°C selama 10 minit. Urea formaldehid (UF) telah digunakan sebagai pengikat. Kekuatan lenturan, kekuatan ikatan dalaman, pembengkakan ketebalan, penyerapan air, pereputan kulat, kerosakan anai-anai, dan penanaman dalam tanah kepada bod partikel telah dianalisa. Fourier Transform Infrared (FT-IR) spektroskopi telah digunakan untuk mengesan kehadiran kumpulan berfungsi yang terdapat dalam bod partikel yang dihasilkan. Penguraian dan prestasi haba kepada bod telah dinilai menggunakan Termogravimetri Analisis (TGA). Imbasan Mikroskopi Elektron (SEM) adalah untuk melihat perubahan struktur bod yang dihasilkan sebelum dan selepas rawatan. Berdasarkan kepada keputusan kajian, bod partikel yang dirawat dengan rawatan air panas lebih tinggi dari segi modulus keanjalan, modulus kepecahan dan kekuatan ikatan dalaman berbanding bod partikel yang diperbuat dariapada partikel yang tidak dirawat. Penambahan bahan pengawet ke dalam urea formaldehid telah meningkatkan ketahanan bod dengan penurunan kadar kehilangan berat pereputan oleh kulat, kerosakan akibat anai-anai dan penanaman dalam tanah. Berdasarkan piawaian British, penilaian kepada semua bod telah memenuhi keperluan kekuatan ikatan dalaman untuk bod partikel jenis P2, P3, P4, dan P5 kecuali bod yang diperbuat daripada partikel yang dirawat dengan sodium hidroksida (NaOH). Walau bagaimanapun, semua bod tidak memenuhi piawaian untuk penyerapan air dan pembengkakan ketebalan. Berdasarkan kajian ini, kajian lanjut adalah diperlukan untuk menambahbaikkan sifat-sifat fizikal bod partikel batang kelapa sawit dengan pelbagai rawatan.

PROPERTIES OF PARTICLEBOARD MADE FROM TREATED OIL PALM TRUNK PARTICLES

ABSTRACT

This study was conducted to examine the effects of particle pre-treatment on the properties of particleboard made from oil palm trunk particles by evaluating the physical, mechanical and biological durability properties. A total of nine types oil palm trunk particleboards were manufactured from different particles treatment (untreated, hot water and NaOH) with different preservative addition (0.06% and 0.1%) at a target density of 0.65 g/cm^3, pressed at 150°C for 10 minutes. Urea formaldehyde (UF) was used as the binder. Bending strength, internal bonding (IB) strength, thickness swelling, water absorption, fungal decay, termite decay and soil burial of the particleboards were analyzed. Fourier Transform Infrared (FT-IR) spectroscopy was used to detect the presence of functional groups that exists in the manufactured particleboards. The decomposition and thermal performance of the boards were evaluated by Thermogravimetric Analysis (TGA). Scanning Electron Microscopy (SEM) was employed to view the structural changes of manufactured boards before and after treatments. Based on the outcome in this study, particleboards made from particles treated with hot water have the higher modulus of elasticity (MOE), modulus of rupture (MOR), and IB strength compared to particleboards made from untreated particles. The addition of preservative in the urea formaldehyde increased the durability of the boards with the reduction of weight loss in fungal decay, termite decay and soil burial. According to British standard BS EN 319 (1993), all the evaluated boards mostly fulfilled the requirement of IB strength for particleboard type P2, P3, P4 and P5 respectively excluding boards made from particles treated with sodium hydroxide (NaOH). However, all boards did not meet the satisfactory standards for thickness swelling (TS) and water absorption (WA).

Based on this study, it showed that further research is required to improve and enhance the physical properties of oil palm trunk particleboards with various treatments.

1.0 INTRODUCTION

1.1 Research background

Malaysia has a large oil palm plantation, which is mostly situated in Peninsular Malaysia areas. The oil palm trees are productive and planted only to get fruit bunches for producing oil about 25 years. After this age, the oil palm trees will be cut down for replanting because no longer economical to harvest. The plantation owners will face a huge problem to dispose oil palm trunks. Therefore, Malaysia has potential to convert these trunks into value-added materials such as particleboard, plywood, laminated veneer lumber (LVL) and papermaking.

Oil palm trunks are considered as nonwood resources residues from agricultural activities, which are inexpensive, renewable sources and environmentally friendly. These nonwood resources have a potential to replace the utilization of rubberwood as raw materials in particleboard industries. By replacing the utilization of rubberwood with oil palm trunks, this could overcome the limited supply of rubberwood. Oil palm trunks are also categorized as nondurable materials as rubberwood. According to Zaidon et al. (2008), particleboard manufactured from non-durable materials such as rubberwood could encourage the biological attacks if exposed to the moisture. From a previous study by Ahmad et al. (2011), oil palm trunk particles can be used for particleboard manufacturing but need to improve the quality aspects before can be utilized commercially. The utilization of oil palm trunk particles in binderless particleboard manufacturing were widely used by previous researchers as Boon (2014), Lamaming (2012), Baskaran et al. (2012) and Hashim et al. (2011a, 2011b, and 2010a). Thus, oil palm trunk particles only can be utilized after proper treatments to improve the properties.

Generally, vascular bundles and parenchyma tissues are component in oil palm trunks. The parenchyma tissues are low in density and contain very high sugar and starch. The ability of parenchyma in absorbing water is high compared to vascular bundles (Mhd Ramle et al., 2012). This showed that vascular bundles are suitable as raw materials for particleboard manufacturing. In general, sugar and starch are soluble in water and sodium hydroxide (NaOH). Therefore, before it can be utilized commercially, an effective pre-treatment need to apply to the oil palm trunk particles to remove parenchyma tissues. In a previous study by Ramli et al. (2002), pre-treatment of empty fruit bunch fiber with water and NaOH was effective to remove oil for manufacturing of medium density fiberboard. Norul Izani et al. (2012) revealed that all the medium density fiberboard properties were improved after the boiling treatment of empty fruit bunch fiber. According to Meon et al. (2012) and Mohd Edeerozey et al. (2007) from their previous study of kenaf fiber, showed that NaOH treatment has improved the tensile properties of the fiber. However, there is still no record about this pre-treatment application to oil palm trunk. Thus, this phenomenon indicated the potential of pre-treatment with hot water and NaOH could be applied to the oil palm trunk particles.

The oil palm trunks, which are considered as nondurable resources, are easily attacked by the biological agents as wood rotten fungi and termites because of the high content of sugar and starch in parenchyma tissues. Besides pre-treatment of oil palm trunk particles with hot water and NaOH, the addition of chemical preservative needs to be applied to prevent from biological attacks. This is appropriate with the previous study by Zaidon et al. (2007), who mentioned that the addition of preservative chemicals is necessary to increase the inherent resistant to decay and insect attack possessed by the nondurable resource. In addition, by improving the durability of the board with preservative will prolong the end use of the products. The utilization of chromate copper arsenate (CCA) and boron as preservatives were widely used by previous researchers. Hashim et al. (1994) studied the effect of vapor boron to the mechanical properties of boards. Zaidon et al. (1998) studied the properties and durability of boron-treated particleboard. Kartal and Clausen (2001) studied the leachability and decay resistance of particleboard made from acid extracted and bioremediated CCA-treated wood. Zaidon et al. (2003) studied the resistance of CCA and boron-treated rubberwood composites against termites, *Coptotermes curvignathus* Holmgren. Awoyemi (2005) studied the effect of borate pre-treatment on the hygroscopic and swelling properties of heat-treated wood. These researchers indicated that the addition of CCA and boron could improve the durability of products against biological attacks. However, CCA and boron are hazardous to the human being. Thus, the search for another alternative preservative, which is less chemical, less hazardous, and more environmentally friendly, is urgently needed to replace boron and CCA. Zaidon et al. (2008) mentioned that pyrethroids are possible groups of chemical preservatives to change the utilization of boron and CCA. On the other hand, there is still a lack of utilization of preservative that is more organic, friendly use and safe to handle. One of the alternatives chemical preservatives that can be used is cypermethrin-based preservative solutions.

Cypermethrin is a pyrethroid insecticide, which kills insects that eat or contact with it (Anonymous, 1998). According to Harp (2005), cypermethrin is an insecticide used in agricultural and residential applications. This synthetic pyrethroid is generally used to control pests of vegetable crops (Anonymous, 1996). While, according to Anonymous (1989), cypermethrin is widely used to control pests such as cockroaches and termites in stores, warehouses, industrial buildings, houses, and apartments. The properties of cypermethrin as insecticide are also for the protection of wood products from insect such as borer and termite attack (Anonymous, 2010a). Cypermethrin is an organic solvent-based preservative and soluble in water which is more suitable to replace boron and CCA. However, to my best knowledge, there is no study undertaken on the application of cypermethrin-based preservative on nonwood resources. Therefore, this research will investigate the potential of pre-treatment particles and the addition of cypermethrin-based preservative for particleboard manufacturing.

1.2 Research objectives

The general objective of this research is to study the durability of the board by preservative treatment. The specific objectives are:

1. To determine the influence of different pre-treatments on the physical and mechanical properties of the boards.
2. To examine the effects of cypermethrin-based preservative treatment on the physical and mechanical properties of the boards.
3. To investigate the performance of the treated boards when subjected to fungal and termite attacks.

2.0 LITERATURE REVIEW

2.1 Oil palm industry

The oil palm tree or *Elaeis guineensis* originated in Africa (Bakar et al., 2008). This oil palm tree has been introduced to various parts of the tropics especially in Malaysia and Indonesia since the 1970s to obtain the fruits for palm oil production (Tomimura, 1992). According to Bakar et al. (2008), the first commercial oil palm plantation was commercialized in Malaysia at Tennamaran Estate, Selangor in 1917.

Malaysia and Indonesia became the most important country in the world with huge planted areas of oil palm tree (Bakar et al., 2008). These days, Malaysia has a total of 5.39 million hectares of oil palm plantation in 2014 compared with 5.22 million hectares in 2013 (Anonymous, 2014). These figures represent an increasing of 3.11% from the year 2013 to the year 2014 as shown in Table 2.1.

Table 2.1 Oil palm planted area and output in Malaysia

	Jan - Dec 2014	**Jan - Dec 2013**	**Change (Vol)**	**Change (%)**
Planted area (ha)	5,392,235	5,229,739	162,496	3.11
Production (tonnes)				
Crude palm oil	19,666,953	19,216,459	450,494	2.34
Crude palm kernel oil	2,277,382	2,269,822	7,560	0.33
Closing stocks (tonnes)				
Palm oil	1,902,306	1,987,111	-84,805	-2.72
Palm kernel oil	299,003	343,705	-44,702	-13.00

Source: Malaysian Palm Oil Council (2014)

Oil palm trees are usually grown for oil production from the fruit bunches. The oil palm tree is effective for its fruit bunches only for 25-30 years. After this age, the oil palm trees are usually felled for replanting because no longer economical for oil production (Bakar et al., 2008). The residues from the oil palm trees which consist of the trunks, fronds, and empty fruit bunches are normally left in the field without any utilization and usually burned which lead to many environmental problems. The oil palm trunks, fronds, and empty fruit bunches are considered as lignocellulosic materials which can be converted into value-added products. These residues are cheap, extensively available and renewable. The utilization of these materials was widely used in research for the production of plywood, particleboard, and other composite products as shown in Table 2.2. However, the utilization of these materials is still in small quantity and still not been economically utilized because of the imperfections that need to be improved before it can be widely commercialized.

2.1.1 Oil palm trunk as raw materials

Oil palm tree belongs to monocotyledon and it is erect with a trunk or bole 12 inches of more in diameter (Bakar et al., 2008; Tomimura, 1992). The oil palm trunk consists of vascular bundles that are randomly embedded in the parenchyma group tissues (H'ng et al., 2011). Generally, oil palm trunk also consists of cellulosic fibers cemented by lignin, which is similar to wood, and the feature of its structure is closer to hardwood (Bakar et al., 2008). Thus, oil palm trunk has a potential to replace the consumption of wood as raw materials in the wood industry.

The utilize of oil palm trunk to convert into value-added product still under research. Many efforts have been done among researchers to convert this material to wood products as solid wood, veneer-based products, plywood-based products and particle-based products. The value-added products from oil palm trunks are exhibited in Table 2.2.

Table 2.2 Value-added products from oil palm trunks

Products	References
Binderless particleboard	Boon 2014 Baskaran et al. 2012 Lamaming 2012 Hashim et al. 2011a, 2011b, 2010a
Plywood	Hoong et al. 2013a, 2013b, 2012 Loh et al. 2011
Impregnated oil palm wood	Bakar et al. 2013a
Particleboard	Ahmad et al. 2011
Laminated veneer lumber	Sulaiman et al. 2009

In Malaysia, about 80% of the furniture industries are using rubberwood as raw materials (Sulaiman et al., 2008). Furniture industries include wooden furniture and wooden panel are using rubberwood as raw materials. Therefore, the utilization of oil palm trunk as raw materials in particleboard manufacturer can replace the utilization of rubberwood. A previous study by Mhd Ramle et al. (2012), mentioned that parenchyma cells have a high ability in taking up water compared to vascular bundles. In addition, high starch content in parenchymas is a reason of fungi grow rapidly on the surface of the oil palm trunks (Tomimura, 1992). Thus, the vascular bundles are more suitable for particleboard manufacturing. Ahmad et al. (2011) found that oil palm trunk can be used in particleboard manufacturing. In previous studies by Boon (2014), Lamaming (2012), Baskaran et al. (2012) and Hashim et al.

(2011a, 2011b and 2010a) revealed that oil palm trunk is also having a big potential in binderless particleboard manufacturing.

2.2 Particleboard

Particleboard is a composite material product made from wood particles, which are bonding between particles with adhesive using heat and pressure. The particleboard can be classified according to its density as shown in Table 2.3.

Table 2.3 Classification of particleboard according to density

Density (kg/m^3)	Classification
250 - 400	Low density
400 - 800	Medium density
800 - 1200	High density

Source: Abdul Khalil and Hashim (2004)

It is commonly used for interior applications in furniture and construction industry. Furniture parts, wall paneling and kitchen cabinet are some examples of particleboard usage, which is widely produced in wood industry for interior uses. According to Anonymous (2015a), in January-April 2015, the export of particleboards achieved RM137 million which is 2% from all export timber products in Malaysia. China is the largest particleboard importer from Malaysia with 28% and reached RM38 million.

In particleboard industries, particleboard manufacturing process involves several steps including chipping, screening, drying, blending with adhesive, mat-forming, pre-pressing, hot pressing and finishing (Boon, 2014). The first process is chipping the selected raw materials in the form of logs, branches or wood residue.

This process is to obtain the required size length and thickness of particles by reducing the size of wood using hammermill. Screening is to separate between required size and the particles that not achieve the required size. In this process, only required size and length will be used for the next step.

Particles will be dried in the dryer during the drying process to obtain suitable moisture content to produce the high-quality board. This process to obtain the required moisture content about 2% to 7% before mixing with liquid resins (Youngquist, 1999). Blending is the process of mixing particles with adhesive and additives. Since most application of particleboard is for interior uses, the adhesive frequently used in particleboard making is urea formaldehyde resin (Youngquist, 1999). Additional additives such as wax and preservative will be added during this process. A small amount of preservative was added for some application to improve the durability of the board (Haque et al., 2013).

The mixture of the particles will be placed into an even mat to be formed into a board. In this process, particles will be distributed evenly into the mat. Pre-pressing is the process to consolidate the particles with adhesive and reduces the thickness of the mat before hot pressing. Hot pressing is a process by setting the specific temperature and pressure to cure the adhesives. This process will form a bonding between particles to obtain the required thickness of the board. Finishing is the last process in particleboard making including trimming and sanding to obtain the required length, width and the desired appearances before it can be shipped to the supplier.

2.2.1 Adhesive

In the wood-based industry, the adhesive is a valuable material in particleboard manufacturing which acts as a binder. The adhesives typically made with a thermosetting resin that holds the wood fiber together (Youngquist, 1999). According to Saheb and Jog (1999), this type of adhesive most commonly used because of its resistant to high temperatures and highly durable.

Formaldehyde resin is one of the thermoset resin based synthetics that usually used in wood-based panel industry. Such resins include phenol formaldehyde, urea formaldehyde, and melamine formaldehyde. These adhesives have been selected depending on the suitability of end use of the product. For example, urea formaldehyde resin is widely applied in particleboard manufacturing due to its suitability for interior applications.

2.2.1.1 Urea formaldehyde (UF)

Urea-formaldehyde resins are thermosetting resin formed from the reaction of two monomers, urea and formalin (Dunky, 1998). This type of adhesive was patented in 1920 then commercialized around 1937 (Pizzi and Mittal, 2003). The advantages of urea formaldehyde resins are they can cure from room temperature to 150°C, press times and temperature can be varied also much cheaper than phenol formaldehyde (Youngquist, 1999).

The utilization of UF is most important in wood-based panel industry as a major consumer such as particleboard, plywood, and fiberboard. According to Pizzi (1990), UF resins are most extensively used binders for lignocellulosic materials especially for interior wood adhesives. Urea-formaldehyde resins are widely chosen in the manufacture of decorative products due to the lowest cost thermosetting adhesive resins, water solubility, and resistance to microorganisms, excellent thermal properties and inherently light color (Akyuz et al., 2010; Youngquist, 1999; Conner, 1996). Therefore, the wood panel industry especially particleboard is a major consumer of UF resin.

2.3 Particle pre-treatment

Pre-treatment is applied to the lignocellulosic materials by different techniques such as physical treatment, heat treatment, and chemical treatment. In the wood industry, pre-treatment applied to the materials in a different form as solid, particle, fiber, and powder. The purpose of pre-treatment is to remove lignin and hemicellulose, reduce the crystallinity of cellulose and increase the porosity of lignocellulosic materials (Harmsen et al., 2010; Kumar et al., 2009).

During the past few years a large number of pre-treatment methods for lignocellulosic biomass such as woods, grasses and bamboo have been developed and investigated by various researchers including alkali treatment, heat treatment, acid treatment and biological treatment (Boon, 2014; Brodeur et al., 2011; Kumar et al., 2009). Many researchers have studied the efficacy of pre-treatment to the lignocellulosic materials to the end product as shown in Table 2.4.

Oil palm trunk is considered as a lignocellulosic material, which is its parenchyma tissues contain high sugar and starch which are susceptible to biological attack such as fungi (Bakar et al., 2008; Tomimura 1992). In addition, parenchyma tissue, which contains starch and sugar, are soluble in water and NaOH. Thus, this study will focus the pre-treatment of oil palm trunk particle with hot water and NaOH treatments to reduce the starch content in parenchymas.

Table 2.4 Previous study of pre-treatment by researchers

Raw materials	Pre-treatment	Product	Reference
OPT particle	Soaking in sulphuric acid Steaming	Binderless particleboard	Boon 2014
Oil palm EFB	Soaking in NaOH Boiling in water	Medium density fiberboard	Norul Izani et al. 2013, 2012, 2011
Kenaf fiber	Soaking in NaOH Boiling in NaOH	-	Meon et al. 2012 Mohd Edeerozey et al. 2007
OPT particle	Boiling in water	Binderless particleboard	Lamaming 2012
Betula pubescens (birch)	Steaming	Solid wood	Awoyemi 2005
Oil palm EFB	Soaking in NaOH Boiling in water	Medium density fiberboard	Ramli et al. 2002

2.3.1 Hot water

Hot water treatment is one of the methods commonly used among researchers for lignocellulosic materials. This method has been used in wood-based industry to treat empty fruit bunches and oil palm particle as shown in Table 2.4. In this method, the materials are treated by boiling in water with certain temperature and time. For example, empty fruit bunches were boiled in hot water with temperature 100°C for 30 minutes (Norul Izani et al., 2013).

Norul Izani et al. (2012) reported that treatment of empty fruit bunches with hot water improved the dimensional stability and the mechanical properties of the medium density fiberboard. Ramli et al. (2002) revealed that hot water treatment reduced the oil content in empty fruit bunches. However, oil palm trunk particles were boiled in hot water with temperature 60°C for 6 hours and the result showed that the mechanical properties of binderless particleboard made were decreased (Lamaming, 2012).

2.3.2 Sodium hydroxide (NaOH)

Generally, the chemical pre-treatment as alkali, acid and salts can be applied to degrade lignin, hemicellulose and cellulose from lignocellulosic materials (Behera et al., 2014). Sodium hydroxide (NaOH) was used by many researchers to treat lignocellulosic materials such as empty fruit bunch and kenaf fiber as shown in Table 2.4.

Mohd Edeerozey et al. (2007) revealed that NaOH can modify and clean the fiber surface, increase the surface roughness, and stop the moisture absorption process of the kenaf fiber. Alkalization treatment also improved the tensile properties of the short kenaf fibers compared to untreated short kenaf fibers (Meon et al., 2012). However, a previous study by Norul Izani et al. (2012) mentioned that soaking empty fruit bunch fibers in NaOH is the worst method because reduced the strength properties of medium density fiberboard. On the other hand, NaOH was effective for removing the residual oil in empty fruit bunch fiber (Norul Izani et al., 2011; Ramli et al., 2002). Thus far, no study has been investigated on the pre-treatment of oil palm trunk particle using NaOH for particleboard manufacturing.

2.4 Preservative treatment

Preservative treatment is applied to the wood product as a protection from fire, chemical degradation, weathering, and biological attack (Archer and Lebow, 2006). The oil palm trunks are generally considered as non-durable materials to biological attack similar as other wood species in Malaysia like rubberwood. These non-durable materials were chosen for particleboard manufacturing because of the availability in large scale and low cost. However, these materials are not resistant to biological attack such as fungal, insects and termite especially for untreated particleboard if exposed to moisture. Therefore, preservation is an important method in the wood-based panel industry, especially for non-durable materials to enhance the durability of the end product.

The purpose of preservative treatment is to extend the end use of a product by increasing the durability of the product manufactured. Therefore, to protect the end product from degradation by biological organisms, it must be necessary to treat with a preservative such as chemicals. Nowadays, there are a few chemical preservatives such as boron compounds and chromate copper arsenate (CCA) is most commonly used (Zabel and Morrell, 1992). However, a boron compound and CCA becoming less popular due to their high toxicity and risk to the human being (Zaidon et al., 2008; Boon, 2009). These days, people are more concerned with an environmental problem. They prefer to choose the less toxic and unharmful products. Nowadays, many researchers looking for environmentally friendly preservative chemicals to increase wood properties including the durability and the physical properties (Durmaz, 2015). Thus, previous study by Zaidon et al. (2008), it is revealed that pyrethroids are possible groups of chemical preservatives that may change the utilization of boron and CCA preservatives. In fact, the pyrethroid preservatives were widely used by many researchers as shown in Table 2.5. Basically, these kind of preservative will act as antifungal agent and insecticide.

Table 2.5 Preservative treatment of wood products

Raw materials	Product	Preservative treatment	Method	Reference
Eucalyptus obliqua, Pinus radiata	Solid wood, laminated veneer lumber	Permethrin	Impregnation	Cookson et al. 2009
Rubberwood, Oil palm EFB	Particleboard	Permethrin, deltamethrin, boric acid	Mix with adhesive	Zaidon et al. 2008
Rubberwood, Oil palm EFB	Particleboard	Deltamethrin, boric acid	Soaking	Zaidon et al. 2007
Betula pubescens (birch)	Solid wood	Borate	Impregnation	Awoyemi 2005
Rubberwood	Particleboard	Alphamethrin	Mix with adhesive	Jasni and Sulastiningsih 2004
Rubberwood	Oriented strand board, particleboard, laminated veneer lumber	CCA, boron	Spraying	Zaidon et al. 2003
Rubberwood	Particleboard	Boric acid	Mix with adhesive, Spraying	Zaidon et al. 1998
Mix wood	Medium density fiberboard, Particleboard Oriented strand board	Boron	Vapor phase	Hashim et al. 1994

2.4.1 Antifungal agent

The antifungal agent is a chemical preservative that is used in order to inhibit or kill the fungi by damaging the cell components of fungi (Boon, 2009). In the wood industry, the antifungal agent is commonly applied to preserve wood and wood product from fungal attack including soft rots, white rots, and brown rots. On the other hand, the antifungal agent is also applied in many sectors as food industries, environmental, medical and pharmaceutical field.

As we know, the requirements of organisms to grow in wood are oxygen, temperature, food, and moisture. The only way to prevent the growth of organisms is to limit the supply of food by chemical treatment because it is difficult to control the temperature, oxygen and moisture (Connell, 2005). Boon (2009) mentioned that the effectiveness of antifungal mechanism via chemical agent depends on time, temperature, pH, and concentration.

2.4.2 Insecticide - Cypermethrin

Insecticides are substances produced from chemical or biological products to control insect pests (Lima et al., 2012). It is a pesticide that used to kill and reduce the insects attacks by disrupting insect nervous system (Anonymous, 2015b). It is also widely used in many sectors including agriculture, wood industry and industrials building. Nowadays, the utilization of toxic and harmful preservatives such as CCA is unnecessary because these have been replaced with pyrethroids such as permethrin and cypermethrin (Acher and Lebow, 2006).

According to Anonymous (1998), cypermethrin is a pyrethroid insecticide, which is a synthetic chemical similar to the pyrethrins in pyrethrum extract. The chemical formula for cypermethrin is $C_{22}H_{19}O_3NCl_2$ (Anonymous, 1989).

Cypermethrin is an organic solvent, which protects products from insect attack (Anonymous, 2010a). Zaidon et al. (2008) revealed that the efficacy of insecticide depends on the level of toxicity in the formulation of preservative and the retention of active ingredients in the board. Referring to Table 2.5, the utilization of pyrethroid insecticides such as permethrin and deltamethrin were widely used by researchers. However, in my knowledge, the utilization of cypermethrin in the wood industry as protection to wood products is still unknown and need to be investigated.

2.5 Wood degradation

Wood and wood products are easy to biodegrade by various biological agents. According to Shupe et al. (2015), the three primary sources of wood degradation are fungi, insects and weathering with four basic requirements including moisture, oxygen, temperature, and food. Basically, biodegradation may affect the physical and mechanical properties of wood. The changes in wood properties after biodegradation including loss of weight, reduce in strength and reduce in dimension (Zabel and Morrell, 1992). The common sources usually found in wood degradation are wood rotting fungi, termites and borers (Boon, 2014). According to Bakar et al. (2013b), the oil palm trunk has a high level of starch content and is very exposed to white rot fungi and termite attack.

2.5.1 Wood rotten fungi

Wood rotten fungi is the microorganisms that attack wood and cause degradation. This microorganism attack woody plant to obtain food. Basically, requirements for organisms to grow in wood are oxygen, food, moisture between 25% to 100% of dry-wood weight and temperature range from 10°C to 35°C (Shupe et al., 2015).

Basically, wood rotting fungi are categorized into three groups including brown rot, white rot, and soft rot. According to Shupe et al. (2015), these different fungi will attack three different components of wood namely cellulose, hemicellulose and lignin. Brown rot fungi break down cellulose and hemicellulose. White rot fungi break down lignin, cellulose and hemicellulose, while soft rots are able to break down cellulose and hemicellulose faster than lignin but this type of fungi grow slower than brown rot and white rot fungi (Boon, 2009; Leonowicz et al., 1999). The previous studies of fungal strain against oil palm trunk products are shown in Table 2.6.

Table 2.6 Previous study of fungal strain against oil palm trunk products

Raw materials	Product	Fungi	Reference
Oil palm trunk	Particleboard	*Pycnoporus sanguineus* *Fusarium palustris*	Boon 2014
Oil palm trunk	Impregnated wood	*Pycnoporus sanguineus*	Bakar et al. 2013b
Oil palm trunk	Plywood	*Pycnoporus sanguineus*	Loh et al. 2011

2.5.2 Termites - *Coptotermes curvignathus*

Termites are classified as insects called Isoptera and closely related to cockroaches because of their behavioral and ecological similarities (Meyer, 2009). Termite colony consists of reproductive forms, workers, soldiers, and immature individuals (Verma et al., 2009). According to Meyer (2009), termites are an important part of the community of decomposers. They will decompose the cellulose in woody plant and other plant material as their source of food. Termites become economic pests because they damage wood and wood products including human house, building materials, and other commercial products (Meyer, 2009).

Subterranean termites, *Coptotermes* spp. is the most economically important of urban pest insects in Asia, which cause a lot of economic damage in Indonesia and Malaysia (Adfa et al., 2015). According to Bong et al. (2012), *Coptotermes curvignathus* has been identified as major pest insect to oil palm plantation on peat land. This species is also a serious pest for structural timber buildings (Sajap and Yacob, 1997). According to Lee (2002), *Coptotermes curvignathus* is common structural pests and usually attack houses built in an area where rubber trees were previously planted. Table 2.7 showed the previous study of *Coptotermes curvignathus* against oil palm trunk products.

Table 2.7 Previous study of *Coptotermes curvignathus* against oil palm trunk products

Raw materials	Product	Reference
Oil palm trunk	Impregnated wood	Bakar et al. 2013b
Oil palm trunk	Plywood	Loh et al. 2011

3.0 MATERIALS AND METHODS

The overall experimental flow chart started from raw materials preparation, panels manufacturing, testing and characterization of particleboard manufactured are illustrated in Figure 3.1.

3.1 Raw materials preparation

The main raw material used in this study was oil palm trunk. The age was 25 years and obtained from oil palm plantation. The oil palm trunks were chipped and ground into required size ranging from 0.5 mm to 5 mm. The particles were dried in the oven maintained at 50°C. The particles then were screened to get the required size. The adhesive UF was supplied by Malayan Adhesive Company Sdn. Bhd., Shah Alam. Cypermethrin preservative was supplied by Arch Wood Protection Malaysia, Kuala Lumpur. This preservative treatment was applied by mixing with adhesive and hardener, ammonium chloride (NH_4Cl).

3.2 Particle pre-treatment

In this study, the oil palm particles were divided into two groups, untreated and treated. The purpose of this pre-treatment was to remove starch and sugar. Table 3.1 displays the types of treatments.

Table 3.1 Types of particle treatment in this study

No.	Treatment	Description
1	Untreated	Untreated particles
2	Hot water	Boiling with water
3	Sodium hydroxide (NaOH)	Soaking with 2% NaOH

Source: Norul Izani et al. (2013, 2012, 2011) and Ramli et al. (2002)

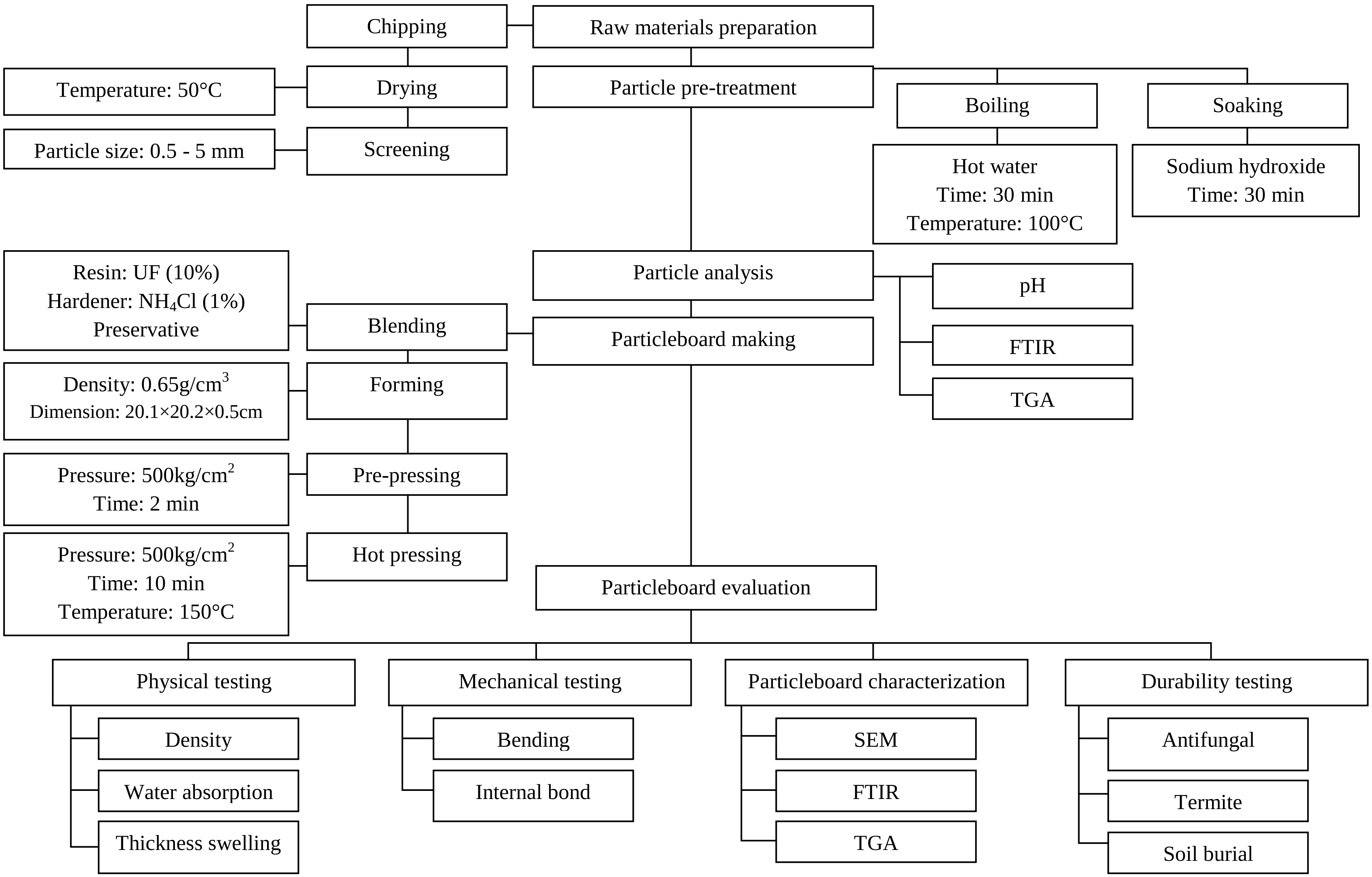

Figure 3.1 The overall experimental flow chart

3.2.1 Boiling with water

The oil palm particles were boiled with hot water at temperature 100°C for 30 minutes (Norul Izani et al., 2013). The particles were then filtered and dried in the oven at temperature 50°C for 24 hours to obtain a moisture content range of 6% - 8%.

3.2.2 Soaking with sodium hydroxide (NaOH)

The oil palm particles were soaked at room temperature for 30 minutes in 2% sodium hydroxide solution (Norul Izani et al. 2013, 2012, 2011; Ramli et al., 2002). Treated particles were filtered out and then re-dried in the oven.

3.3 Preservative treatment

A preservative used in this study was cypermethrin. The cypermethrin was added to the particles by mixing with the adhesive. The cypermethrin ($C_{22}H_{19}O_3NCl_2$) was mixed in adhesive as recommended by the supplier with two parameters 0.06% and 0.1% (weight/weight of oven dry particles).

3.4 Particle analysis

3.4.1 Determination of particles pH

The pH values of all particles include untreated and treated were determined according to the Technical Association of Pulp and Paper Industry (TAPPI T 509 om-83, 1983). In this analysis, approximately 1 g of particles were mixed with distilled water, stirred and soaked at room temperature for 1 hour. The pH values of particles were measured using a pH meter (Mettler Toledo).

3.4.2 Fourier transform infrared spectroscopy (FTIR) analysis

The Fourier transform infrared spectroscopy (FTIR) analysis was carried out to identify the existence of functional groups in the different treatment of particles. For this analysis, the oil palm trunk particles were ground into powder form. Approximately 1 mg of powder form particles based sample was mixed with 99 mg of potassium bromide (KBr). The mixture was compressed to form about 1 mm thickness of pellet. The sample was examined using a Nicolet infrared spectrophotometer (Avatar 360 FTIR E.S.P). The analysis was recorded between wavenumbers of 4000 cm^{-1} and 400 cm^{-1} with a resolution of 4 cm^{-1} to identify the functional groups for each sample.

3.4.3 Thermogravimetric analysis (TGA)

Thermogravimetric analysis was carried out using a Perkin Elmer TGA 7 thermogravimetric analyzer to determine the thermal decomposition of the sample. Approximately 10 mg of the sample in powder form was placed in a pan. The values were recorded in the range temperatures between 30°C to 800°C with a heating rate at 20°C/min under a nitrogen atmosphere.

3.5 Particleboard making

Table 3.2 Types of board manufactured in this study

Types of board		
A Untreated board	D Hot water board	G NaOH board
B Untreated board + 0.06 % preservative	E Hot water board + 0.06 % preservative	H NaOH board + 0.06 % preservative
C Untreated board + 0.1 % preservative	F Hot water board + 0.1 % preservative	I NaOH board + 0.1 % preservative

A single layered particleboard 20.1 cm × 20.2 cm × 0.5 cm with six replication for each condition were manufactured with a target density of 0.65 g/cm^3. Pre-weighed oil palm particles, untreated and treated were blended separately with 10% (w/w of particles) of UF resin and 1% (w/w of solid resin) hardener. Preservative was added to the oil palm particles by mixing the solutions (0.06% and 0.1 % w/w of oven dry particles) with the adhesive. The furnish then was formed in a former, pre-pressed at a pressure of 500 kg/cm^2 for two minutes before being hot-pressed for 10 minutes at 150^0C under a pressure of 500 $kg/cm^{2.}$ The types of board produced were shown in Table 3.2.

3.6 Particleboard testing

3.6.1 Determination of physical properties

3.6.1.1 Density

The density of the samples was determined according to British Standard BS EN 323 (1993) with modification of the sample size. The test specimens were cut into 5 cm × 5 cm × 0.5 cm dimensions. The length, width and thickness of the specimens was measured using a caliper. The mass of each specimen was weighed. The density of the board was calculated using Equation 1.

$$\text{Density } (g/cm^3) = \frac{m}{v} \qquad [1]$$

where, m = mass of the sample (g)

V = volume of the sample (cm^3)