A COMPARATIVE STUDY OF MECHANICAL AND THERMAL CONDUCTIVITY PROPERTIES OF AN INSULATION PARTICLEBOARD

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DECLARATION

I declare that this project report entitled "A Comparative Study of Mechanical and Thermal Conductivity Properties of an Insulation Particleboard" is the result of my own except as cited in the references.

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : ....

Name : ....

Date : ....

DEDICATION

To my beloved, mother and father.

ABSTRACT

In the last few ten years, many researchers have tried to find new material that would be used in the industry with better properties and friendly environmental. Nowadays, as the earth in a critical condition with much pollutions, green energy technology has been introduced as a way to save the planet. Because of the pressure on slow-growing and save trees, many studies have been carried out to evaluate new, environmentally friendly raw materials for the production of particleboards. In this situation, agricultural waste has shown remarkable potential as a particleboard raw material, since the chemical composition of such waste is similar to that wood. Sugarcane bagasse is a potentially exciting substitute for wood in particleboards manufacturing because it has a similar composition than wood but in different proportions composition approximately 32–34% cellulose, 19–24% hemicellulose, 25–32% lignin, 6–12% extractives, and 2–6% ash. Sugarcane bagasse also has great tensile strength and hardness. Thus, it has the potential to be used as reinforcement in composites. This study aims to fabricate new particleboard insulation composites with low thermal conductivity coefficients using bio-based waste materials. Using wasted material such as sugarcane bagasse would be more green energy and save the environment. The percentage of fiber and polypropylene content use is 10%:90%, 20%:80% and 30%:70%. The result of testing is then compared to the previous research. From the result, sugarcane fiber composite is suitable for making low thermal conductivity particleboard.

ABSTRAK

Dalam beberapa tahun kebelakangan ini, banyak penyelidik telah berusaha mencari bahan baru yang akan digunakan dalam industri dengan sifat yang lebih baik dan persekitaran yang aman. Pada masa kini, sebagai bumi dalam keadaan kritikal dengan banyak pencemaran, teknologi tenaga hijau telah diperkenalkan sebagai cara untuk menyelamatkan planet ini. Oleh kerana tekanan pada pokok tumbuh perlahan dan menyelamatkan, banyak kajian telah dilakukan untuk menilai bahan mentah baru yang mesra alam untuk pengeluaran papan partikel. Dalam keadaan ini, sisa pertanian telah menunjukkan potensi yang luar biasa sebagai bahan mentah papan zarah, kerana komposisi kimia sisa tersebut serupa dengan kayu itu. Tebu tebu adalah pengganti yang berpotensi menarik untuk kayu dalam pembuatan papan partikel kerana mempunyai komposisi yang serupa dengan kayu tetapi dalam komposisi perkadaran yang berbeza kira-kira 32–34% selulosa, 19–24% hemiselulosa, 25–32% lignin, 6–12% ekstrak, dan 2–6% abu. Tebu juga mempunyai kekuatan tegangan dan kekerasan yang hebat. Oleh itu, ia berpotensi untuk digunakan sebagai penguat dalam komposit. Kajian ini bertujuan untuk membuat komposit penebat papan partikel baru dengan pekali kekonduksian terma yang rendah menggunakan bahan buangan berasaskan bio. Menggunakan bahan terbuang seperti tebu akan menjadi lebih banyak tenaga hijau dan menyelamatkan alam sekitar. Peratusan penggunaan kandungan serat dan polipropilena ialah 10%: 90%, 20%: 80% dan 30%: 70%. Hasil pengujian kemudian dibandingkan dengan kajian sebelumnya. Dari hasilnya, komposit serat tebu sesuai untuk membuat papan partikel kekonduksian terma rendah.

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First of all, I feel so grateful to Allah that I have given me this strength and ability to complete my project report. I want to take this opportunity to provide thank, especially my supervisor, Dr. Md Isa bin Ali for his kindness, guidance, and assisting me in completing my project and report. Besides, I appreciate because of his useful advice help me a lot through the progress and development of my project. The most needed, he gives me enthusiastic encouragement and support in many ways.

I want to voice a great thanks for the advice, supervision, and suggestion from my friend that show me how to be successful in writing the thesis and completing the project. Also, I would like to thank you for my beloved family as my backbone in supporting me and giving me some motivation for my strength during all the progress of my project.

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UHMWPE	Ultra High Molecular Weight Polyethylene
ISO	International Organization for Standardization
MPa	Mega Pascal
GPa	Giga Pascal
℃	Degrees Celsius
%	Percentage
k	Thermal Conductivity
Q	Heat Flow
L	Length
ΔT	Temperature difference
T2	Final Temperature
T3	Heated section Low Temperature
T6	Cooled section High Temperature
T7	Cooled section Mid Temperature

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In the last few decades, many researchers have tried to find new material used in the industry with better properties and friendly environmental. Nowadays, as the earth is in a critical condition with much pollution, green energy technology has been introduced to save the planet. Therefore, citizens are increasingly worried about the use of green materials for the industry to preserve the environment. Many research projects have currently been undertaken to find the latest alternative to current industrial materials.

In the 19th century, modern plywood was invented as the first alternative to natural wood. Plywood is made from thin wood and bonded together with an adhesive. By the end of the 1940s, the particleboard was introduced as a new popular alternative because of the lack of timber available to manufacture plywood affordably (S. A. Abdulkareem, Raji, & Adeniyi, 2017).

Particleboard has been the common building material used in almost all types of construction projects. It was commonly used because it's made from the combination of waste materials and glued together with formaldehyde-based adhesive and synthetic resin and then compressed under hot pressure (Ibe Kevin et al., 2018). Some typical applications of these materials include indoor and outdoor use such as floors, walls, ceilings and office splitters. Conventionally, fibers and wood particles are the most commonly used raw materials in the particleboard industry. Due to slow-growing pressures and the protection of trees, many studies were carried out to determine new eco-friendly raw materials for the production of particleboards.

In this situation, agricultural waste has also shown a huge potential as a particleboard raw material, as the chemical composition of such waste has been close to that of wood. Among the wastes used for producing particleboards are corn cob, coconut husks and sugarcane. A large number of such waste are generated worldwide annually, which are mostly poorly recycled into products of added value.

In Malaysia, 1 tonne of sugarcane has produced for instance, which generally generates around 280 kg of bagasse for one cycle (Daud, Salleh, Salleh, & Straw, 2007). The fibrous are remaining by-product after extracted from sugarcane. Roughly 54 million dry tons of bags are produced annually around the world (Aminudin et al., 2017). Sugarcane bagasse is a potentially exciting substitute for wood in particleboards manufacturing because it has a similar composition than wood but in different proportions composition approximately 32–34% cellulose, 19–24% hemicellulose, 25–32% lignin, 6–12% extractives, and 2–6% ash (Haghdan, Renneckar, & Smith, 2015). Sugarcane bagasse has also a satisfactory modulus and tensile strength. Thus it has the potential to be used as reinforcement in composites.

In this technological era, the industrial factory fields are the source of human quality life. The environment problem like heat pollution also occurs because of this factor. Many researchers have attempted to reduce this kind of pollution. It based on the use of insulator materials such as porous materials like wool and fiber. Agriculture also wastes some of the insulator materials, and these materials called green materials. Many types of materials have been manufactured, such as rice straw, hemp, coconut coir and sugarcane.

1.2 PROBLEM STATEMENT

Insulation particleboards are widely used among people in many sectors. However, the existing insulation particleboards usually are entirely made with wood as the primary source. The rapid growth of particleboard in the market has made the demands of wood increasing. Therefore the cost to produce wood particleboard is increasing. The wood itself as resources is limited to obtain due to the massive destruction of trees done by illegal logging activities. The rising temperature also happens because of the illegal logging activities.

Due to this, people living with an unbearable situation with the heat surrounding environment and less privacy of their conversation. Therefore, the world needs to look for alternatives replacing wood for insulated particleboard that made from wasted agriculture such as sugarcane bagasse.

This study aims to fabricate new particleboard insulation composites using bio-based waste materials with low thermal conductivity coefficients. Using wasted material such as sugarcane bagasse is more green energy and save the environment.

1.3 OBJECTIVE

The objective of this project are:

I. To produce a new insulation particleboard with a low heat transfer coefficient.

II. To compare the mechanical performance and thermal insulation this particleboard with previous study.

1.4 SCOPE OF PROJECT

The scope of this study are:

I. Preparation of sugarcane bagasse as raw material for the fabrication of particleboard.

II. The fabrication of particleboard will be conducted with using 10%, 20% and 30% of sugarcane bagasse fiber.

III. The polypropylene will use as binder.

IV. The particleboard will be fabricated using hot press machine.

V. The particleboard will be test on

- Mechanical properties on its tensile strength and hardness
- Thermal insulation conductivity.

VI. The result will be compare with the previous studies of particleboard.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

In this chapter, the literature review is focused on the objective and scope of the project. The purpose of this chapter is to study from past researchers. This chapter contains five main topics, which are the thermal insulation, composite properties, type of binders, the use of natural fiber, and the experimental test.

2.1 THERMAL INSULATION

Thermal insulation is a technology that helps to slow down the rate of heat transfer by reducing the mechanism of heat convection, conduction, and radiation. The thermal insulation function is to maintain the temperature within the building by delaying the heat transfer. By using this method on the building, the energy consumption by the human can be conserved. This statement is supported by Lucero-álvarez, Rodríguez-Muñoz, & Martín-Domínguez, (2016) that said, that thermal insulation can reduce the energy consumption in the buildings. By applying this method in walls and roofs, the uses of daily air conditioning can be reduced.

2.1.1 APPLICATION OF THERMAL INSULATION

Other than the building, the thermal insulation system also appropriates in the automotive sectors. Thermal insulation particleboard can be mounted both on the roof and on the armrest of the door panel. This technology will help improve the thermal comfort of the car and provide passengers with a smoother ride. The lightweight of the composite thermal insulation system installed in a vehicle is assumed can reduce the car's fuel consumption.

According to the present study by Al-Oqla & Sapuan, (2014), the uses of fiber in the automotive industry could already be found in the 1960s when coconut coir being used to make the car seats and polypropylene composites used as substrates for the interior of the car.

2.2 COMPOSITE

2.2.1 Definition of Composite

The composites are each of them retains its characteristics but absorbed into other components to enhance their properties (Florea & Manea, 2019). In the process of producing the composite material, the right types of binders need to be consider. It is supported by Binici, Aksogan, & Demirhan, (2016) that said, strong kind of adhesive or resin, the size, and reinforcement method can influence the product's mechanical properties.

The researchers have done a lot of studies on composite itself. Usually, most studies are carried out to find the mechanical or physical properties of the composite material. Particleboard or panel form product has set as the sample for applying this application. Liao, R., Xu, J & Umemura, (2016), fabricated low density particleboard that contains a composition of sugarcane bagasse, water, citric acid, and sucrose were done with different percentage of densities which is 0.30, 0.35, 0.40, 0.50 g/cm^3. Sucrose and citric acid were initially mixed and diluted into water using the mixer machine under a ratio of 1:1. The concentration of the solution was 30 gram citric acid and 30 gram sucrose per 100 gram solution. The solid additives nitric and sucrose accounted for 10%, 20%, 30%, and 40% of the oven-dried particle was used as an adhesive and then sprinkled onto the particles. The process proceeds by placing homogeneous single-layered into 320 × 320 mm mold. The mold was then hot-pressed at a temperature of 170 °C at 2 MPa for 8 minutes. The board thickness was regulated by 7 mm-thick distance bars. After that, the mold is left to be cooled at room temperature.

2.2.2 Hybrid composition

Hybrid composition materials are defined as the combination of two or more different types of fibers in the same binder. It is possible to obtain new properties or characteristics from a hybrid composite material that is not in a single type of reinforcement. Usually, the hybrid composites material was used to reinforce one material with the other's material to increase the physical and mechanical properties of their combination. Not many researchers study hybrid composite using a source from natural fibers to combine as filler. In hybrid composites, they usually use one natural fiber and one non-natural fiber (glass) combined with a binder.

Zhang & Hu (2014) has done studied hybrid composite using natural fibers as filler. The study used rice straw particles and coir fibers as the filler to reinforce with polypropylene to find the behavior of the hybrid composites. Table 2.1 shows the composition of weighted PP samples, rice straws, and coir fibers corresponding to the fiber content. The composition is prepared by combining it with an internal mixer at 60 rpm speed and 180 °C temperature for 8 minutes. The composite material is then ground to achieve the structural fibers' granular form using a pilot-scale grinder. After that, the granule is dried on a vacuum oven at 130 ℃ for 3 hours. Then the sample is fabricated using a compression molding machine with a pressure of 20 MPa at 190℃. The tested samples are left at room temperature for at least two days before testing.

Table 2.1: Composition of the studied (wt %)

(Source: Zhang & Hu, 2014)

TYPE	Polypropylene content (% by wt)	Rice husk content (% by wt)	Coir fibers content (% by wt)
A	60	30	10
B	60	20	20
C	60	10	30
D	50	30	20
E	50	20	30

2.3 Binder

The binder is a substance or any material which holds or binds other materials together between them. In simple words, the binder serves as the glue that makes composite materials adhesion or cohesion. Binders also called resin or matrix. In this situation, the binder that uses for making particleboard is a synthetic binder. The synthetic binder classified into two types, which are thermoplastic and thermoset. The thermoplastic resin is the polymer that softens to a liquid state in high temperature and then will turn into solid when cooled. The thermoplastic polymer can be molded into a variety of shapes because of these properties, making it applicable to many industries.

On the other side, thermoset polymer is a polymer that is irreversibly hardened by the curing process and often design to be molded into the final shapes. During the curing process, chemical reactions will create extensive cross-linking between polymer chains so they cannot be remolded or softening (Battegazzore, Alongi, Duraccio, & Frache, 2017). Therefore, if the molded shape does not meet the requested form after curing, it will be a total waste.

Examples of conventional thermoplastic resins used today are polypropylene, polyethylene, polyvinyl chloride (PVC), and others. Meanwhile, the examples of thermoset are epoxy, phenol-formaldehyde and so on.

2.3.1 Polypropylene

Polypropylene (PP) is one of the most widely used thermoplastic binders for making many useful products. In 1954, Giulio Natta discovered PP, but commercial production began in 1957 (Hisham A. Maddah et al., 2016). PP is the most widely used thermoplastic because it is very cheap and flexible for molding.

Polypropylene has excellent properties, which make it more suitable for the petrochemical industries. The polypropylene properties are semi-rigid, transparent, excellent chemical resistance, good heat resistance, and good fatigue resistance. Furthermore, polypropylene also has high softening or glass-transition point, high flexing stress resistance, excellent electrical resistance, dimensional stability, a lightweight, low water absorption, and have high impact strength. The detailed properties of polypropylene are shown in Table 2.2.

Table 2.2: Polypropylene properties value

(Source: Hisham A. Maddah et al., 2016)

Properties	**Value**	**Unit**
Density	0.91 - 0.9	g/cm^3
Water absorption	0.01	%
Melting point	160 – 166	^{o}C
Tensile strength	30	MPa
Thermal conductivity	0.12	(W/mK)

2.3.2 Polyvinyl Chloride (PVC)

A layer of fiber-reinforced polyvinyl chloride (PVC) has a heat distortion temperature that is sufficiently greater than the non-reinforced thermoplastic (Stack & Lai, 2011). An extruded fiber reinforced polyvinyl chloride served as a moving mandrel in a manual or continuous process to make the structural component of the invention substantially complex shapes with significant thermoplastic core material performance and strengthen thermosetting content.

PVC has good mechanical properties in terms of hardness and strength. But, its thermal properties is quite dissatisfying. PVC has deficient heat stability properties and easy to melt at low temperatures. PVC can be categorized into two types of body which is a rigid body and flexible body (Albayani, Mirmanto, & Syahrul, 2018). Table 2.3 shows The characteristic of polyvinyl chloride (PVC). The rigid PVC is higher than the flexible PVC, as proved by the study of (Albayani et al., 2018).

Table 2.3: The characteristic of polyvinyl chloride (PVC)

(Source: Albayani et al., 2018)

Properties	**Rigid PVC**	**Flexible PVC**
Density (g/cm^3)	1.30 – 1.45	1.10 – 1.35
Thermal conductivity (W/m.K)	0.14 – 0.28	0.14 – 0.17
Yield strength (psi)	4500 – 8700	1450 – 3600
Flexural strength (psi)	10,500	N/A
Young’s modulus (psi)	490,000	N/A
Compression strength (psi)	9500	N/A
Coefficient of thermal expansion (liner) (mm/mm ^oC)	$5x10^{-5}$	N/A

2.3.3 Phenol Formaldehyde

Formaldehyde is used in manufacturing industries for the synthesis of resins during particleboard formulation. Phenol formaldehyde (PF) resins are used as glue to hold sheets of plywood and particleboard of similar quality together (Ferdosian, Pan, Gao, & Zhao, 2017). Phenol formaldehyde resins provide high physical and mechanical properties with high strength and high moisture resistance. This prevents delamination and provides excellent stability of the temperature. This is because the nature of phenolic resins is more elastic (Cardona & Moscou, 2008).

2.4 Natural fiber

The natural fibers are the renewable sources that can be disposed of at the end of its useful life. This characteristic is called as biodegradable. Biodegradable materials are being used nowadays because it is a renewable and eco-friendly nature to the environment (Song, Murphy, Narayan, & Davies, 2009). Besides, A & VK (2016) also stated that the use of natural fibers in biodegradable is gradually increasing because they are cheap and low in density, have their own unique properties, easy to extract and reduce the energy consumption. Based on the study from Danso (2017), it stated that there are many natural fibers with excellent performance of sound absorption such as kenaf, kapok, sugarcane bagasse, corn cobs, coconut coir, rice husk, and jute stick. Therefore, they are very suitable to be applied in room act as noise reduction. The application of these bio-based materials in automotive industries will give benefits, such as the improvement of mechanical strength and acoustic performance. It also can reduce the weight, fuel, use of energy, and cost. Table 2.4 shows the potential applications of natural fibers.

Table 2.4: The potential uses of natural fibers

(Source: Peças, Carvalho, Salman, & Leite, 2018)

Waste	Industry	Potential uses
Sugarcane bagasse	Sugarcane mills	Insulation boards
Coconut coir and byproducts	Coconut based	Composites brick and insulation board
Corn cobs and stalks	Agricultural farms	Building boards
Rice husk	Rice mills	Insulation boards / cement
Jute sticks	Jute mills	Roofing /composites
Straw of wheat	Agricultural farm	Fiber board / composites

2.4.1 Sugarcane bagasse

Sugarcane juice is popular to the citizen of Malaysia. The sugarcane juice machine will extract the juice from the sugarcane. This process will leave a waste product of sugarcane. This waste called sugarcane bagasse. After that, the sugarcane bagasse will be going to dispose of. Instead of doing that, the bagasse can be extracted by removing the fiber that can be used to make a useful material like particleboard. It is because sugarcane bagasse is one of the most low cost and abundant lignocellulose materials (Bezerra & Ragauskas, 2016). The lignocellulose is the mixture of lignin and cellulose that reinforces the cell in the sugarcane. The sugarcane bagasse contains 32–34% of cellulose, 19–24% of hemicellulose and 25–32% lignin.

According to Lima, Farinassi, Marin, & Pereira, (2016), the sugarcane bagasse retrieved from a Hawaiian sugar mill. The sugar mill's fresh bagasse contains water (moisture), pith, fiber, and soluble solids which are mainly sugar. Table 2.5 shows the proportion of each by weight.

Table 2.5: Proportion of each content

(Source: Lima et al., 2016)

Content	Percentage by weight (%)
Moisture	42 - 54
Fibers	31 - 37
Pith	12 - 15
Soluble solids	2 - 6

From the Onoszko & Hallersbo, (2015) analysis in terms of availability, she concluded that bagasse has the most massive supply. The benefit of bagasse is that it is low in thermal conductivity. It is the most suitable renewable source for producing the boards and panels due to its environmentally friendly characteristics, which required less chemical resin to produce. Sugarcane can help to reduce the environmental issue, which is global warming due to the carbon absorption through the cycle of sugarcane photosynthesis as it grows.

2.4.2 Kapok fiber

The kapok is a gigantic canopy tree of the tropical forest. Kapok is from tropical India and for its fibers was widely cultivated in Southeast Asia. Kapok is a tree that is growing quickly, and it can rise to 4 meters per year in full sun, eventually reaching 60 meters in a maximum of its height (Bokhari et al., 2015). The growing kapok tree can produce around 600 until 900 fruits, called seed capsules per year. The kapok fruits are shown in Figure 2.1. Before the fruits are fully maturation, they are being harvested. Each fruit usually contains bundles of 12-15 grams of fiber. The fibers are manually separated from the seeds by human labor. Individual fibers are 18 mm long, with a diameter of 30-36 µm.

Figure 2.1: The kapok fruits

(Source: ‘Google image’ https://www.google.com/search?q=kapok+fruit)

The characteristic of kapok is moisture-resistant, resilient, quick-dry and buoyant. The chemical and mechanical properties of kapok fibers are shown in Table 2.6. The kapok fibers have low strength and inelasticity properties, therefore, making them not suitable for the spinning process (Chaiarrekij, Apirakchaiskul, Suvarnakich, & Kiatkamjornwong, 2012). The kapok fiber surface has waxy cutin content and makes them hydrophobic (water repellent) and oleophilic (oil absorbent). Therefore kapok fibers are ideal materials for oil removal applications. This fibers also used for making insulation materials, pillows and mattresses.

Table 2.6: Chemical and mechanical properties of kapok fibers
(Source: Purnawati et al., 2018)

Chemical properties				
Cellulose %	Hemi-cellulose %	Lignin %	Wax %	Moisture %
35 – 50	22 – 45	15-22	2–3	N/A
Mechanical properties				
Density (g/cm^3)	Elongation %	Tensile strength (MPa)	Young's modulus (GPa)	
1.474	1.2	93.3	4	

2.4.3 Kenaf fiber

Kenaf fiber is a natural fiber that has been extracted from the Hibiscus Cannabinus L plant. Kenaf fiber is usually can be found in northern Africa and Asia. Kenaf is an annual crop of bast fiber for the warm season. It could grow under any climate of weather conditions, and when it matures, it can grow of height up to 6 m and 3-5 cm in diameter. It only takes 4 or 5 months to be harvested because of the rapid growth of kenaf fiber. The kenaf's ability for a high rate of soil consumption of nitrogen and phosphorus is the primary reason for Kenaf's very high interest (Bourguignon, 2016).

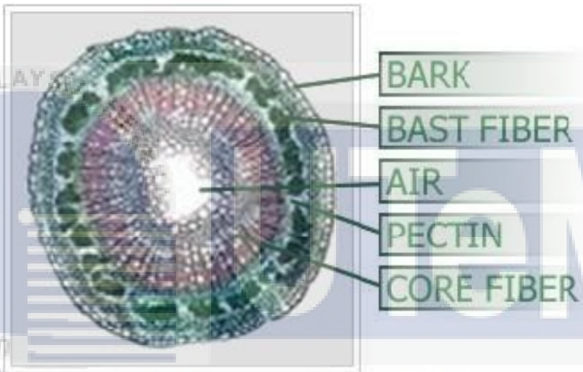

Figure 2.2: The position of bast and core fiber

(Source: 'Google image'

https://www.google.com/search?q=difference+of+kenaf+bast+fibre+and+kenaf+corefibre)

Kenaf plant consists of two-part, which are bast fiber and core fiber, and their position is shown in Figure 2.2. In average, it contains 60% - 65% of core fiber and 40% - 35% of bast fiber. The chemical properties of kenaf fiber are approximately 60% of cellulose, 25% hemicellulose, and 8% of lignin. Figure 2.3 shows the impact strength result between bast fiber and core fibers. The correlation of kenaf bast and kenaf core can be seen in figure 2.3. The overall strength of kenaf bast fiber is higher compared to the kenaf core fiber.

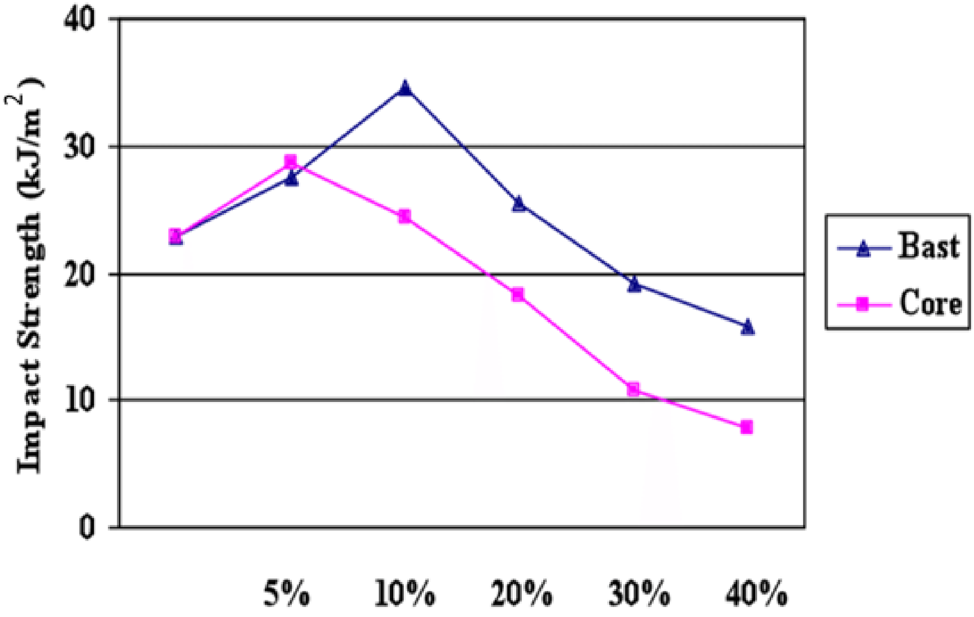

Figure 2.3: The impact strength of kenaf bast and kenaf core

(Source: Ishak, Leman, Sapuan, Edeerozey, & Othman, 2010)

Kapok fibers can be used in various applications such as handbag, canvas, ropes and can even use as fillers for reinforcing particleboard. Many advantages can get from kenaf fiber uses. Kenaf fiber is cheap for the demand, and its extraction process is easy to do. Shahar, Sultan, Shah, & Safri (2019) shows the step of kenaf fibers preparation. The first step of the extraction is the debarking process. For the debarking process, the kenaf trunks soaked in the water for one day long. Then, the trunks will be taken out of the water and put on canvas to be dried. The bast fiber will slowly start to debarking by own from the core part. The final step of the extraction is the drying process, which is the fibers will left under the sunlight for three days. Then the fibers are ready to use.

2.4.4 Coconut coir

Nowadays, many manufacturing industries have applied coconut fiber for making their products. After the coconuts were collected for their fruit and delicious juice, the outer shell of coconut or called as coconut husk was normally being throw away and wasted. Also called as coconut coir, the coconut fiber is a natural fiber that has been extracted from the coconut husk.

The coconut coir usually has around 50 – 300 mm in length. The coconut coir's chemical properties can be seen in Table 2. Coconut coir degradation is much slower compared to other natural fibers due to the large proportion of lignin content. But in contrast, the lifetime of the coir can be as long as 5 to 10 years. According to Rahman & Khan, (2007), in order to improve the strength properties, the coconut coir will go through the pretreatment process. The fibers are washed roughly 10 times with tap water. The coir was then boiled for 2 hours to eliminate water-soluble chemicals such as sugar, fat and starch. Lastly, the coir will dry under sunlight for 2 days.

Table 2.7: Chemical properties of coir fibers
(Source: A & VK, 2016)

Chemical properties	Percentage %
Water soluble	5.25
Pectin and related compounds	3.00
Hemicellulose	0.25
Lignin	45.84
Cellulose	43.44
Ash	2.22

2.5 Experiment Test

In most experiments in literature, the mechanical test and thermal conductivity are being tested. The mechanical test is tests performed on a particular material to test its strength or reaction to loads. The strength, toughness, elastic modulus, and strain hardening are obtained during this test.

Mechanical tests are being done on a particular material to study its strength or reaction toward loads. Strength, toughness, elastic modulus, and strain hardening are obtained and studied during this test. Mechanical tests consist of tensile test, hardness test, flexural test, and much more. The mechanical test was performed to obtain its properties. At the same time, thermal conductivity also tested to obtain its properties for that material.

2.5.1 Compressive test

The bagasse and banana waste cement brick has been study by Aminudin et al., (2017). He had performed a compressive test by following the American Society of Testing Method, ASTM D695 standard. Six samples have conducted during the test. The sample was mix with a ratio of 1:3, which is the cement to sand and the ratio of water-cement is 0.45%. The bagasse and banana fiber is mixed with mortar with various percentage of fibers, 0%, 2%, 4%, 6%, 8%, and 10%. The test has been tested using the compressive testing machine. Figure 2.4 shows the result of the compressive test carried by Aminudin et al., (2017).

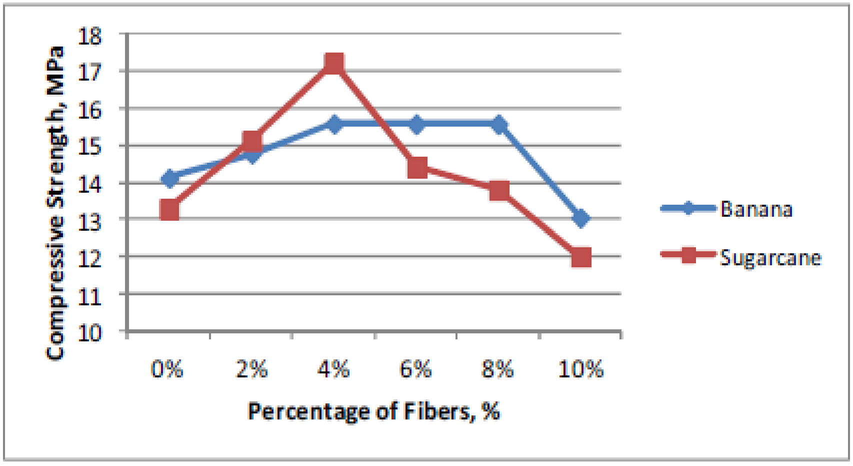

Figure 2.4: Compressive strength against fiber percentage

(Source: Aminudin et al., 2017)

Figure 2.4 shows that a higher percentage of bagasse fiber reduce the strength of the cement brick. It is because the bagasse and the mortar are poorly workability and weakly attached. The mortar contains around 1% of air voids, and mortar will lose its strength if more workability is used. Every 1% of air entrapped on mortar will lose its strength by 4%.

A compressive test also had been conducted by Binici et al., (2016). The study was conducted to test compressive on cement brick with a mixture of cement, corn fiber and gypsum resin. Table 2.8 shows the composition of the mixture. The result of the compressive test is shown in Figure 2.5. The result shows, the higher the amount of gypsum used will lower the brick strength. The test was conducted and follow the ASTM standards.

Table 2.8: Composition mixture of cement brick

(Source: Binici et al., 2016)

Specimens	Cement	Gypsum	Water	Corn fiber
S11	250	100	300	200
S12	200	150	300	200
S13	150	200	300	200
S14	100	250	300	200
S15	50	300	300	200

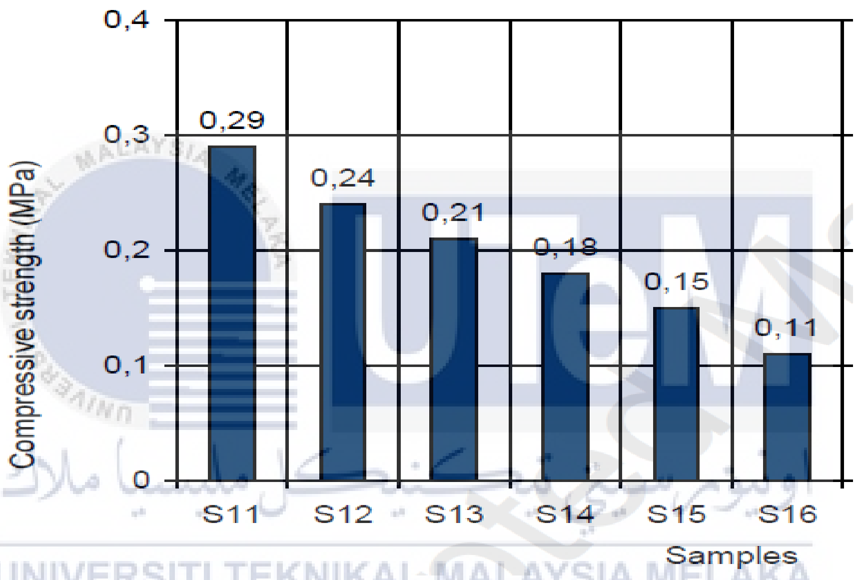

Figure 2.5: Compressive test versus samples

(Source: Binici et al., 2016)

2.5.2 Flexural test

From the study of Binici et al., (2016), he also had conducted a flexural test on the composite cement brick by following ASTM D790 standards. The test was tested using a universal testing machine. The method used for the test is 3 point bending. The composition of the samples is the same as before that have shown in Table 2.6. The flexural test result is shown in Figure 2.6.

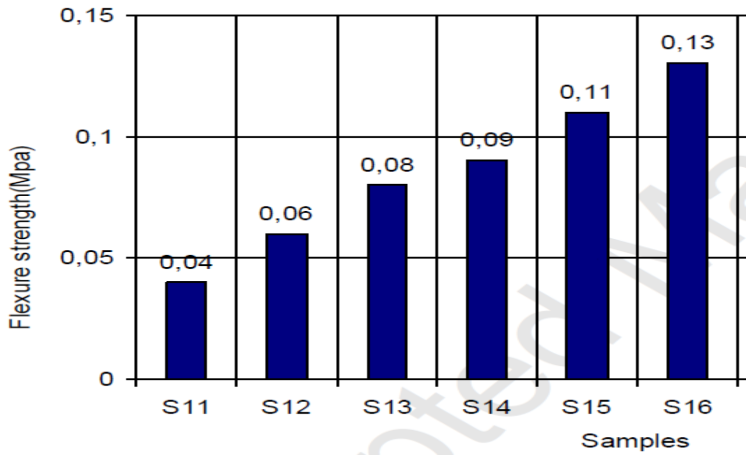

Figure 2.6: Flexural test versus samples

(Source: Binici et al., 2016)

From the figure, the flexural strength of samples increases when the content of gypsum resin increases.

Based on Hart et al., (2017) earlier research, they used a three-point bending method to test the flexural test. The calibrated hydraulic testing machine (INSTRON 3365) was used to test the samples and follow followed ASTM D790 standard.

ASTM D790 also being followed by Garoushi, Lassila, & Vallittu (2012) and the three point bending flexural test is being used. Eight specimens with a length of approximately 76 mm, a width of 12 mm and a thickness of 3 mm are tested.

2.5.2 Hardness test

Jenarthanan, Marappan, & Giridharan, (2019) has carried out the hardness test using a Rockwell hardness method on his study. ASTM D2240 standard has been followed during the test. They used this method to measure the hardness of the E-Glass and coconut coir mix with epoxy and polyester. The result of the test is shown in Figure 2.7. From the result, the

E-Glass fiber mix with epoxy composites has the highest value of hardness. It indicates that the resin is an important factor in determining the hardness of the material.

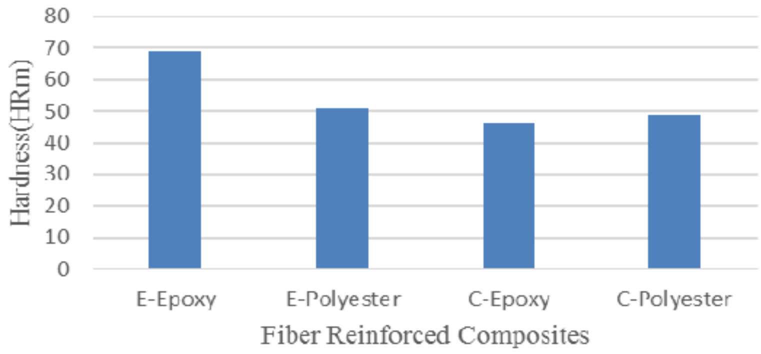

Figure 2.7: Rockwell Hardness Test

(Source: Jenarthanan, Marappan, & Giridharan, 2019)

Figure 2.8 shows the graph of hardness comparison of banana fibers with the addition of nano-silica and without nano-silica. The result shows that nano-silica addition contributes to a composite will decrease its hardness. Thus the banana fibers without nano-silica are better in terms of hardness properties.

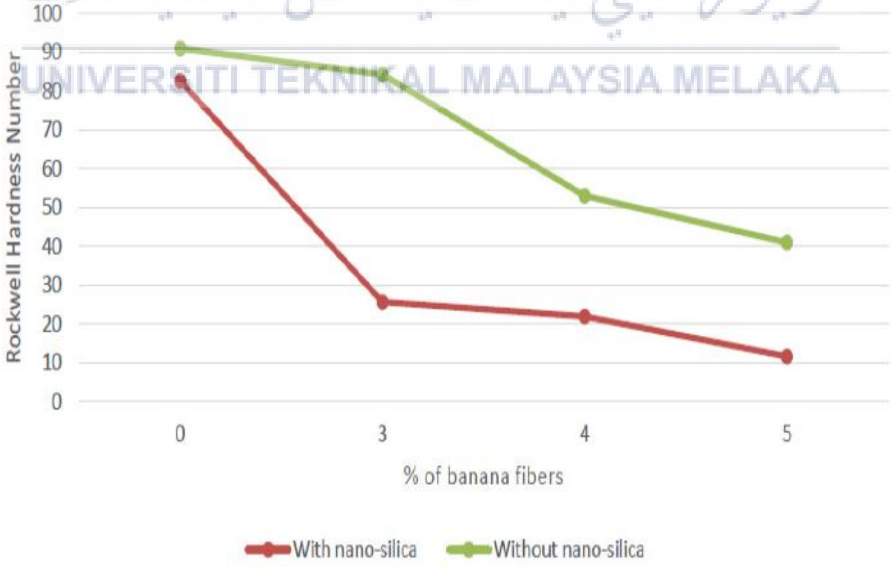

Figure 2.8: Rockwell hardness

(Source: Rahul et al., 2017)

2.5.3 Tensile test

The tensile test aims to measure the mechanical properties of a particular sample on its strength, toughness, flexibility, strain hardening, and elastic modulus. A previous study of Spiegelberg et al., (2009) conducted a tensile test on UHMWPE and followed the ASTM D638 standard. The sample was using the 'dogbone' shape method, as shown in Figure 2.9.

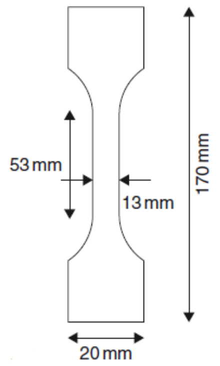

Figure 2.9: Tensile test 'dogbone' sample

(Source: Spiegelberg et al., 2009)

Figure 2.10 show the graph of the load F and displacement ΔL are tracked and translated into engineering stress and strain.

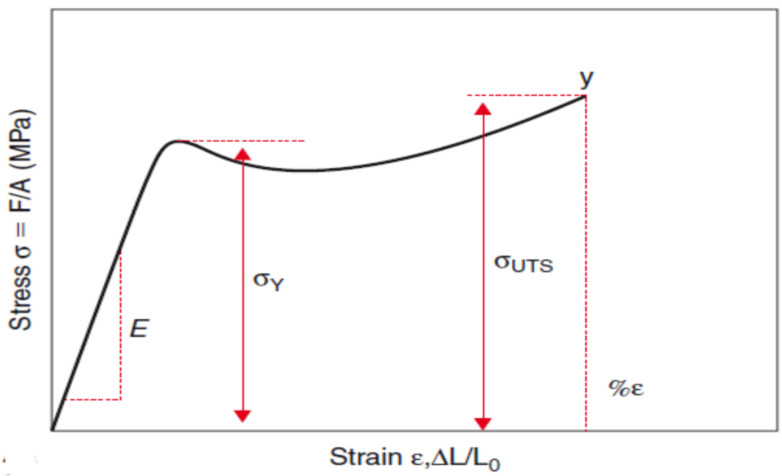

Figure 2.10: Tensile test graph for UHMWPE

(Source: Spiegelberg et al., 2009)

Jenarthanan, Marappan, & Giridharan, (2019) have also carried out the tensile test on his study using a Universal testing machine following ASTM D3039 standard. Figure 2.11 shows the graph of stress versus strain of coconut coir reinforced with epoxy resin and polyester resin. From the graph, coconut coir mix with epoxy have the highest tensile test value compared to the coconut coir polyester mixture.

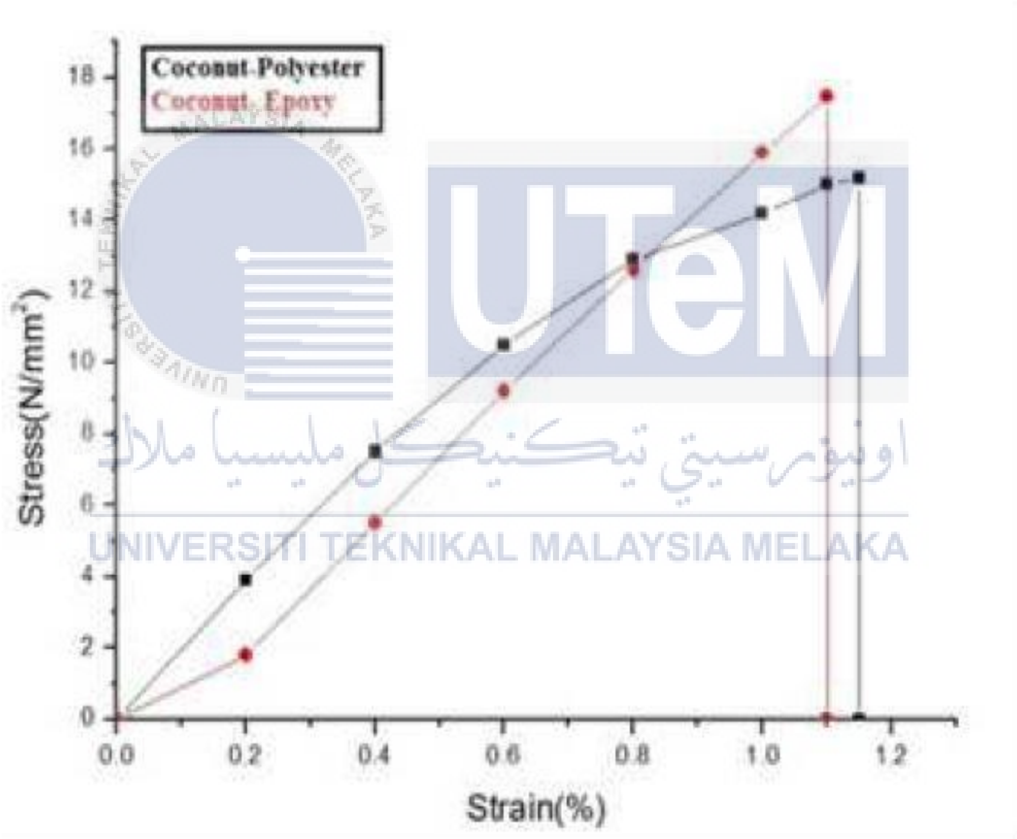

Figure 2.11: Tensile test stress versus strain

(Source: Jenarthanan, Marappan, & Giridharan, 2019)

2.5.4 Thermal conductivity test

The graph of thermal conductivity versus time is shown in Figure 2.12. The thermal conductivity test has been done by Abdulkareem et al., (2016) in their study of biomass composite of thermal insulation properties. The value of thermal conductivity is obtained from the test samples. Thermal conductivity is a material's ability to transfer or conduct heat. The graph shows that sugarcane bagasse has excellent thermal insulation properties due to its low thermal conductivity value.

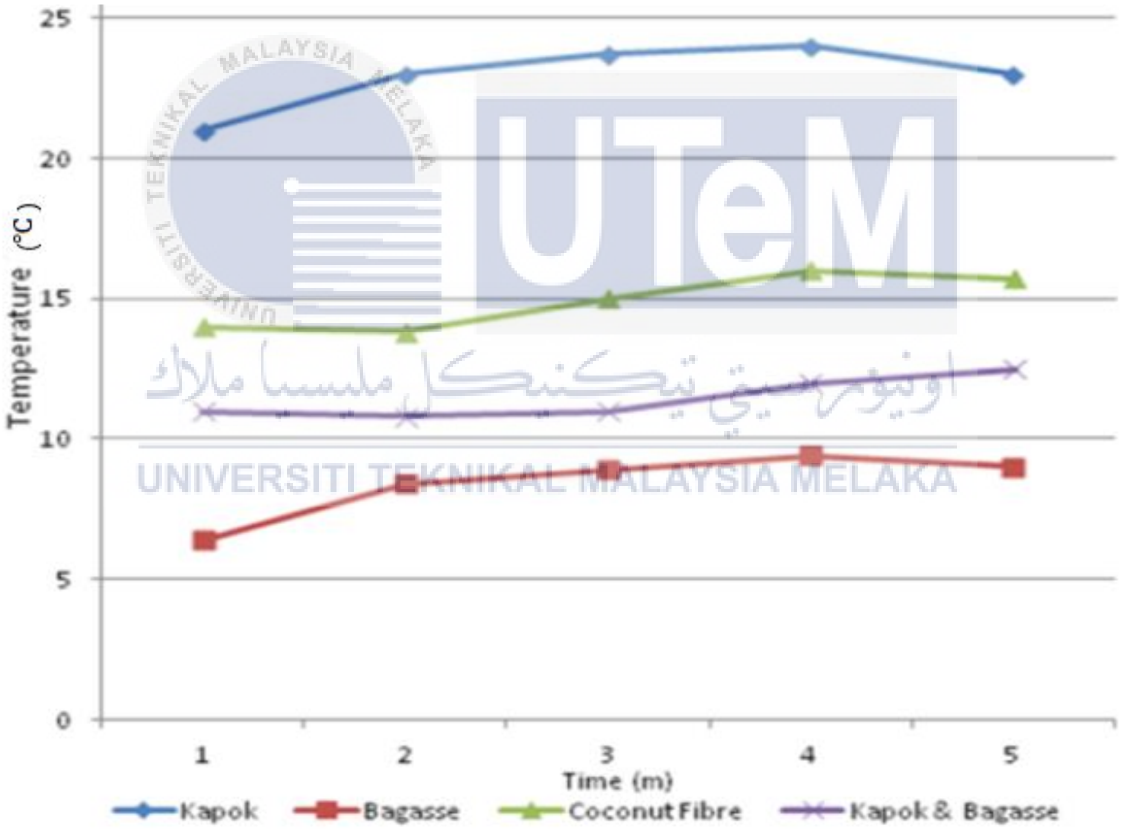

Figure 2.12: Thermal conductivity of biomass composite

(Source: Abdulkareem et al., 2016)

CHAPTER 3

METHODOLOGY

3.1 FLOW CHART PROCESS

The flow chart process in fabricating the particleboard is shown in Figure 3.1. At phase 1, the raw material of sugarcane fiber and polypropylene is prepared. For the fabrication particleboard, the polypropylene resin is provided by the laboratory assistant. The waste of sugarcane will get from the sugarcane stall. Then sugarcane fiber will be extracted from sugarcane, and the fiber will be blend by using blender machine to get the minimum below 2mm of size.

For phase 2, the sugarcane fiber will be mixed with a binder, which is polypropylene on the mold, and then the mold will compress by using hot pressure for 10 minutes. The experiment will be tested on different percentages of fiber, 10%, 20%, and 30% through all the equipment provided at the laboratory.

The last phase will conduct the experiment test on the particleboard, which are the mechanical properties and thermal conductivity. The result of the experiment will be compared with the existing particleboard, and the conclusion can be made.

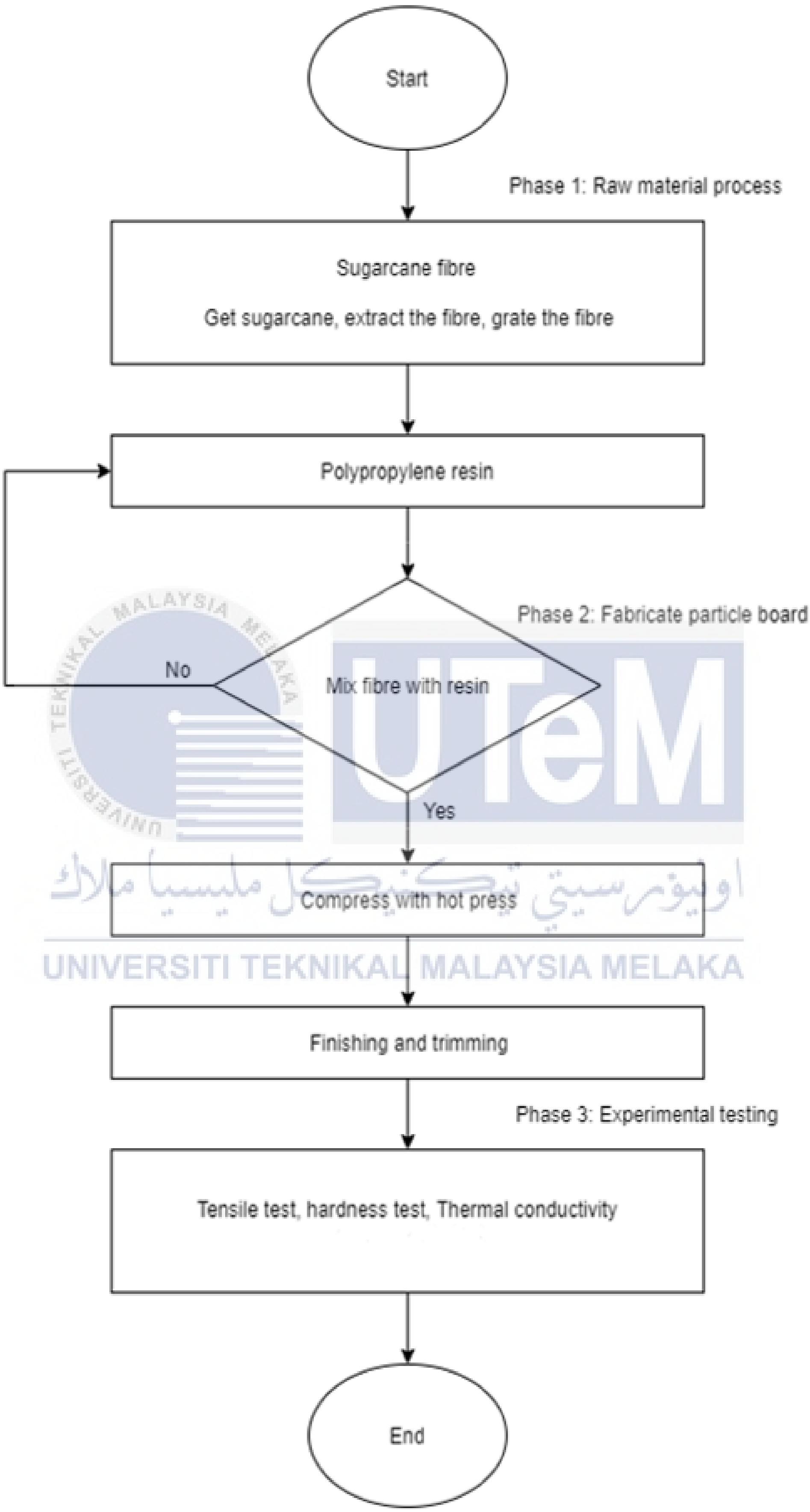

Figure 3.1: The flowchart of particleboard making

3.2 PREPARATION OF RAW MATERIAL

3.2.1 Material selection

The sugarcane waste is retrieved from a sugarcane juice stall at Taman Tasik Utama, Melacca. The sugarcane waste is taken before the stall owner gave it to the organic decomposition factory. Sugarcane and polypropylene are needed to making particleboard. Figure 3.2 shows the example of product sugarcane fiber that made of from fibrous material.

Figure 3.2: Sugarcane particleboard

3.2.2 Sugarcane fiber extraction

The raw material that chosen for this study is sugarcane waste, which is also called as bagasse. Bagasse can be described as the fibrous waste that still remains after the sugarcane stalks are compressed in order to collect their juice. 2 kg of sugarcane waste is prepared for the first phase. The bagasse was dried in the room for 7 days, making the grating process more efficient and smooth. The bagasse raw material is heated for about 30 minutes in the oven at 60 ° C temperature.

The bagasse material is then cut to shorter pieces using a scissor and then blended into a blender to form the fine fibers. These fibers will put in the grinder machine until the fibers are finer. The obtained sugarcane fibers are then sieved using a sieve to obtain sizing fibers ranging 0.35 to 0.5 mm as shown in Figure 3.3. Then sugarcane fibers will mix with resin which is polypropylene based on the composition in Table 3.1.

Figure 3.3: The sieve

3.2.3 Sugarcane fiber extraction chorological

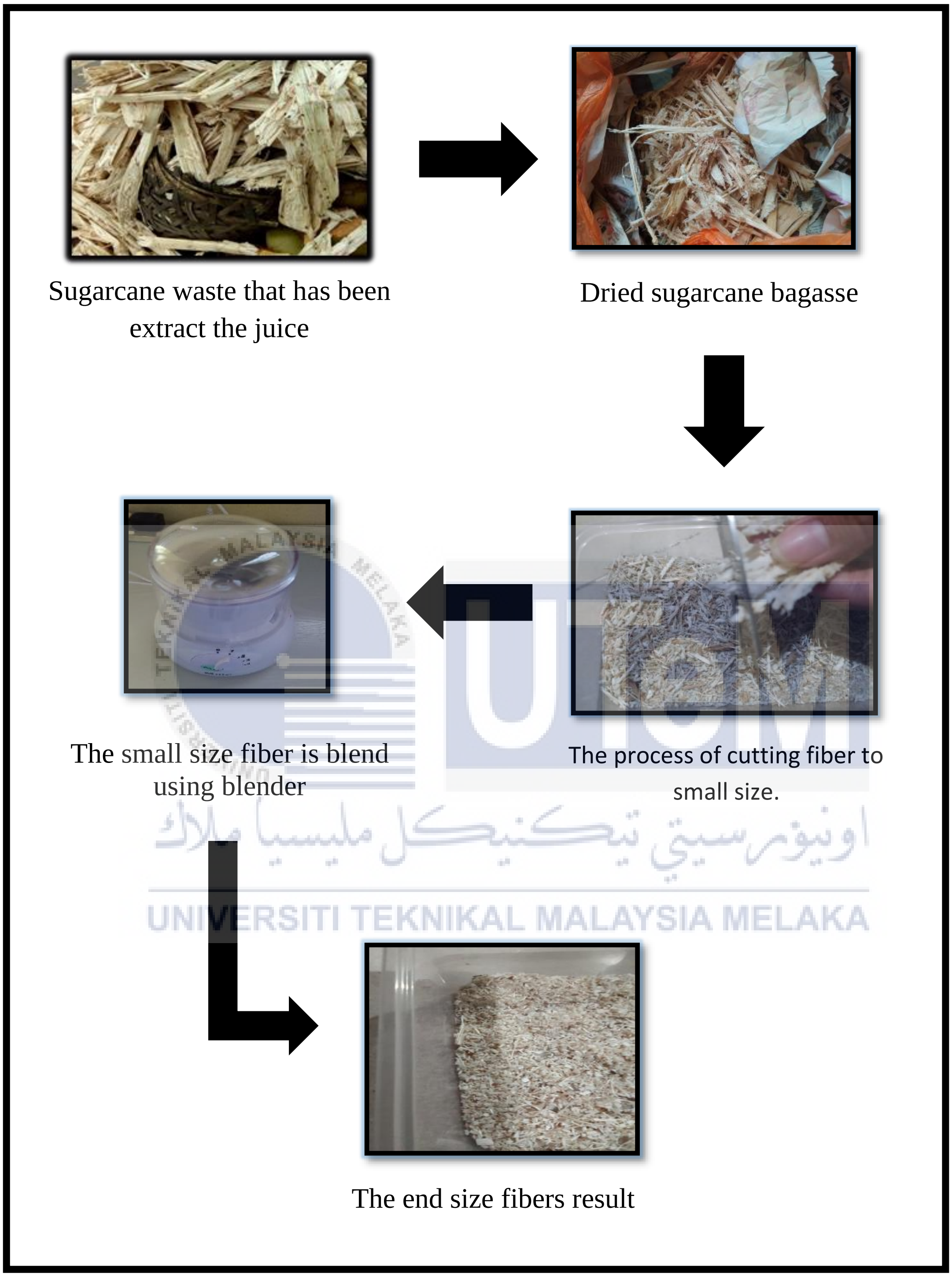

Figure 3.4: The chronological extraction of young coconut

3.2.4 Composition

Table 3.1 show the percentage of sugarcane fibers and polypropylene resin composites for making particleboard.

Table 3.1: Percentage composition for particleboard making

Composition	1	2	3
Sugarcane fibers (wt. %)	10	20	30
Polypropylene (wt.%)	90	80	70

3.2.5 Preparation of resin

The resin that will be used for making the particleboard is polypropylene. The usage of the resin in making the sugarcane particleboard is shown in Table 3.1. The adhesive will be applied to the surface of the particles to bind the particles together. It will also undergo a heating process at 70 °C for 15 minutes to form into a liquid before combining it with fibers. The laboratory assistant prepares the sample of polypropylene resin.

The process of the formation of the polypropylene resin is shown in Figure 3.5. The resin is used as a binder to hold together the material for the fabrication of particleboard. It takes three weeks to obtain the resin powder.

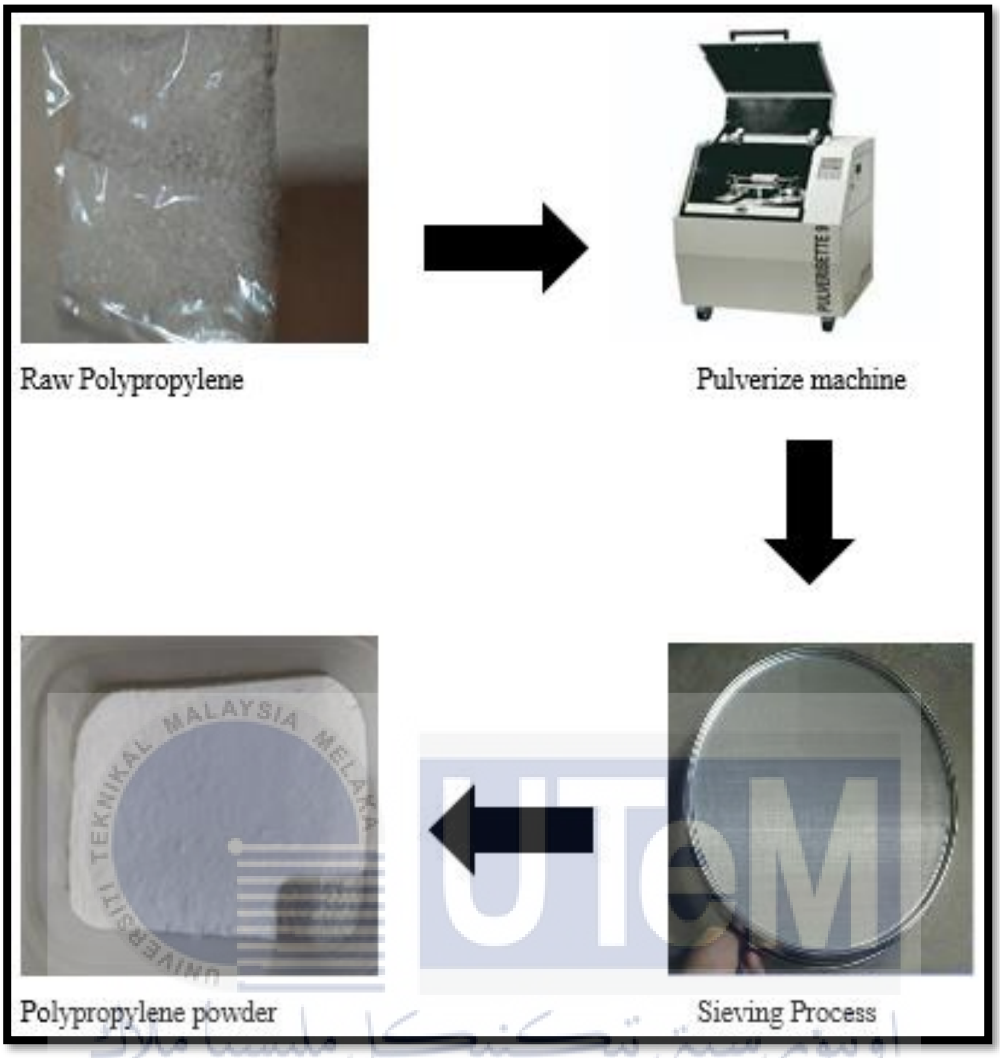

Figure 3.5: Formation of Polypropylene Resin

The raw polypropylene resin was packaging into a plastic packet with 200 gram each pack. The 200 gram of resin was put into the pulverizing machine located at Fasa B (UTEM). For each 200 gram, it needs a 7-time running machine to crush the resin into powder. Each one-time running machine needs 500 seconds to crush partially. After five times running, the machine needs to take a break at least 300 seconds. So it takes 3800 seconds or 1 hour 3 minutes to obtain the resin powder. Then, the sieving process was done to separate the coarse and fine polypropylene powder. The sizing sieve diameter that used is 500 µm. Lastly, all the process were repeated to obtain the maximum value of polypropylene resin.

3.3 FABRICATION OF PARTICLEBOARD

The process of fabricated sugarcane particleboard starts with weighing the sugarcane fibers and the resin powder, which is polypropylene. The percentage composition ratio of the mixture for the fiber: resin is 10%, 20%, 30% : 90%, 80%, and 70%. The total mass of the mixture is 24 grams.

The next process was ball mill. The mixture was put to the synthetics bottle, then placed the bottle in the ball mill machine for 45 minutes to make sure the mixture was mixed well. The hot press machine is preheated approximately to 170 degrees for the hot press process. Then, fill the mixture mixed at ball mill carefully into the mold with the size dimension of 140 mm x 60 mm x 3 mm.

When the hot press machine was reached 170 degrees of temperature, carefully put the mold inside the hot press machine and cautions with the high temperature of the machine. The heating process takes a time of about 15 minutes. After 15 minutes, do the compression process with 500 psi for 5 minutes. Then, the mold was taken out from the machine for the cooling process for 20 minutes. The particleboard was taken out from the mold after completely cooled. Repeat the step for another sample of mixed percentage.

3.4 MECHANICAL PROPERTIES TESTING

The tensile strength, hardness, and thermal insulation conductivity are the tests that will be conducted in this section on the sugarcane fiber. The three samples of particleboard composition in Table 3.1 are prepared for this test.

3.4.1 Tensile Test

The composite samples' tensile strengths were determined with samples of sizes that will be tested using the Universal material tester. Figure 3.6 shows the Universal material tester. This test is conducted to see its material ability to withstand the load. Experiments were carried out compliance to ASTM D638 standards with the speed of 10 mm/min.

Next, the computer will show the result of the graph is plotted between various load and displacement values for the specimen until the sample break. Using Hook's Law formula, the Load-Displacement curve is converted to the stress-strain curve for the analysis of specific tensile properties such as fractured point, toughness, and deformation limit. The calculation of stress and strain are calculated by using Equation 3.1 and 3.2

$$\sigma = \frac{F}{A} \tag{3.1}$$

Where,

σ = Stress

F = Force

A = Area

$$\varepsilon = \frac{L_1 - L_0}{L_0} \tag{3.2}$$

Where,

ε = Strain

L_0 = Original length (mm)

L_1 = Length of stretch (mm)

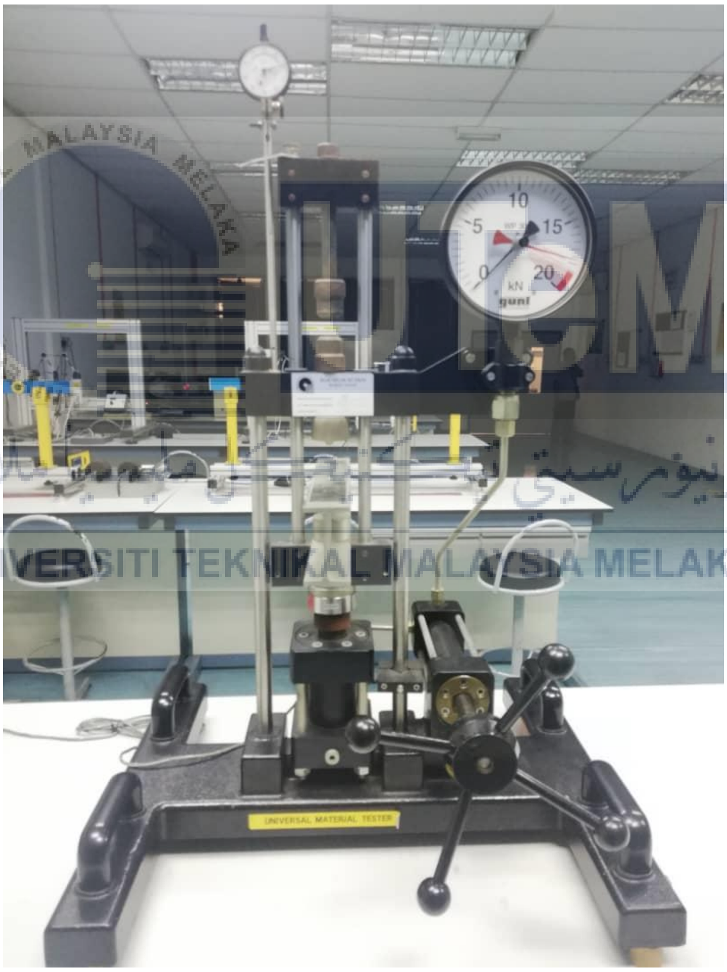

Figure 3.6: Universal material tester

3.4.2 Hardness test

Hardness tests will be carried out using Digital Shore Tester, Durometer. Based on Figure 3.7, Durometer is suitable to measure soft material since the thickness of the sample is 3 mm. The test follows the ASTM D2240 standard. The Durometer shall be pressed on the surface of the specimen until the surface of the board is parallel with it. The Durometer is read after the presser foot has touched the surface of the specimen.. The steps were repeated at another point.

Figure 3.7: Durometer hardness test

3.4.3 Thermal conductivity

The sample's thermal insulation conductivity was measured in a steady-state condition by using Heat Conduction Unit. For this experiment, the new sample will be fabricated in cylinder form, as shown in Figure 3.8. The specimen will fabricate by applying the pressure over a period of time using a piston tube. The pressures are applied on the top of mold and maintained for ten minutes, to obtain adequate strength to secure its thickness, diameter and density. The specimen is then heated in the oven for it to be hardened. The composition of the specimen remains unchanged.

Figure 8: New sample of sugarcane fiber

The new sample will be tested on the heat conduction test, as shown in Figure 3.9. Fourier's law for thermal conductivity is used to calculate thermal conductivity. In the law of Fourier’s, the heat transfer rate (Q) by mean of uniform material is proportional to the temperature drop (T), the area (A), and inversely proportional to the length of (L) of thermal conductivity (K) flow. The thermal conductivity can calculated by using Equation 3.3.

$$Q = kA\frac{\Delta T}{L} \quad (3.3)$$

Where,

Q = Rate of heat flow through board in watts (W)

k = thermal conductivity of board dependent constant of proportionality ($Wm^{-1}K^{-1}$)

A = Cross-sectional area of heat flow (m^2)

ΔT = Temperature difference between ends of board (K)

L = Sample length (30 mm)

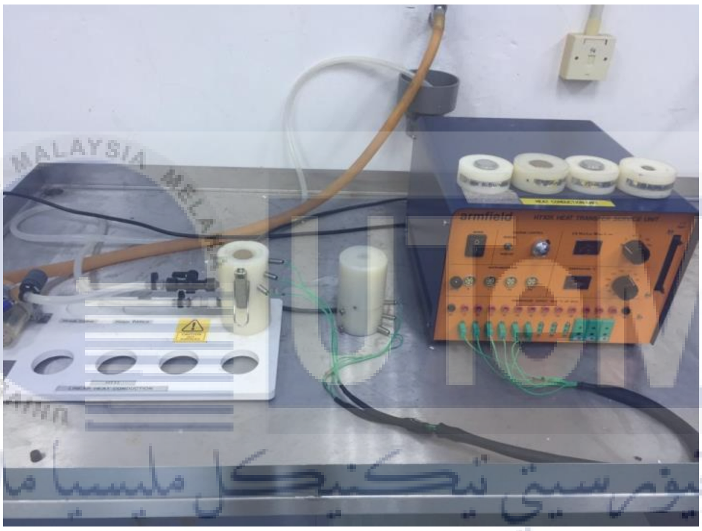

Figure 3.9: Heat conduction tester

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the result from previous studies will be compared, analyzed, and discussed. Three types of test results was presented, which are the result of the hardness test, tensile test, and thermal conductivity test. All the results in this chapter are to confirm that all the objectives were attained and achieved.

4.2 HARDNESS TEST

Digital Shore Tester, Durometer was used to carry out the hardness test. The test followed the ASTM D2240 standard. In all previous studies, all of them were used this method on their research for hardness testing. In this hardness test, the type of fibers that will be compared are sugarcane bagasse, banana fiber, and coconut coir. Table 4.1 shows the data of the hardness test from various kinds of fibers. The temperature for all of the selection fibers of hot-press while fabricating the particleboard is all the same, which is 170 degrees Celsius.

Table 4.1: Hardness test data

FIBER	BINDER	PERCENTAGE %		HARDNESS TEST (N/mm^2)
		FIBER	BINDER	
Sugarcane	Polypropylene	30	70	44.00
		20	80	35.42
		10	90	28.67
Banana	Epoxy	3	97	84.60
		4	96	53.80
		5	95	40.00
Coconut	Polyester	20	80	26.36
		15	85	37.76
		10	90	26.46

From Table 4.1, all the hardness test data are obtained from the previous study. The sugarcane composite data are from Fernea, Manea, Plesa, Iernutan, & Dumitran, (2019), while the data of banana are from the previous study of Rahul et al. (2017). For the coconut the hardness test was done by Onuegbu & Chu (2017). The data shown was the average value that was summed up from each three values taken.

Graph hardness against percentage fibers was shown in Figure 4.1. It shows that the banana composite has the highest value of hardness than the other two fiber. The hardness value for banana decreases as the content of fiber increases. The coconut fiber composite reaches its maximum value of hardness at 15%, and the value of hardness reduction obtained at 20% of the fiber content. As for sugarcane composite, it can be concluded that the amount of hardness is rising when the percentage of fiber increasing. The maximum value of hardness hits when the fiber content at 30%.

The banana composite has the highest value because its mixture contains more than 90 percent of epoxy hardener resin. A combination of 100 percent epoxy alone can get the highest value of hardness, which is 90, according to the studies of Madhukar et al., (2017). From Figure 4.1 also, it can see that the sugarcane composite has a better hardness than the coconut composite. It concludes that the sugarcane composite mixture with polypropylene resin has stronger bonding then the coconut composite mixture with polyester. Sugarcane fibers have a high content of lignin, which contributes to the higher measured hardness of particleboard.

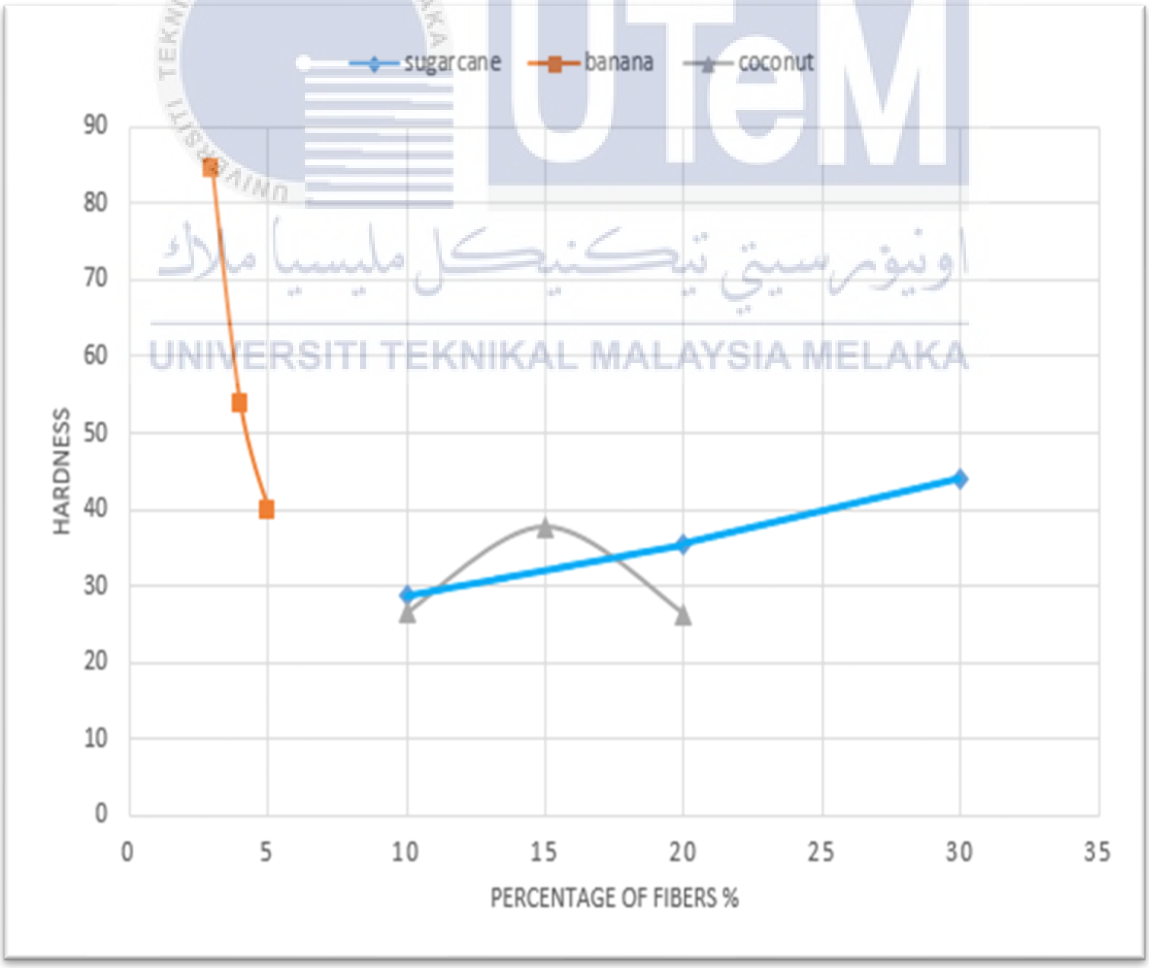

Figure 4.1: Hardness against Percentage Fibers (%)

4.3 TENSILE TEST

Instron Universal Testing Machine was used to carry out the tensile test. The tests were carried out according to ASTM D638 standards. In this tensile test, the type of fibers that will be compared are sugarcane bagasse, corn cob, coconut coir, rice husk, and fonio husk. Table 4.2 shows the data of tensile tests from various types of fibers. The head speed of the testing machine used for all of the selection fibers were 10mm/min.

Table 4.2: Tensile test data

FIBER	BINDER	PERCENTAGE (%)		TENSILE STRENGTH (MPa)
		FIBER	BINDER	
Sugarcane	Polypropylene	30	70	4.49
		20	80	3.13
		10	90	2.82
Corn cob	Cassavas starch	80	20	0.86
		70	30	1.40
		60	40	0.67
Coconut	Polyester	20	80	8.06
		15	85	14.23
		10	90	21.85
Rice husk	Polypropylene	30	70	19.70
		20	80	22.50
		10	90	24.20
Fonio husk	Gum Arabic	80	20	0.36
		70	30	0.56
		60	40	0.72

Table 4.2 shows, all the tensile test data of sugarcane fibers are getting from the previous study of Fernea et al. (2019), while the data of corn cob fibers are from the prior research of Yimsamerjit, Surin, & Wong-on (2007), for the coconut fibers the tensile test was done by Onuegbu & Chu (2017), for rice husk fibers the tensile test was done by Frounchi, Dadbin, Jahanbakhsh, & Janat-alipour (2007) and for the fonio husk fiber the data are from the previous study of Ndububa & Nwobodo (2018). The data shown was the average value that was summed up from every three values taken.

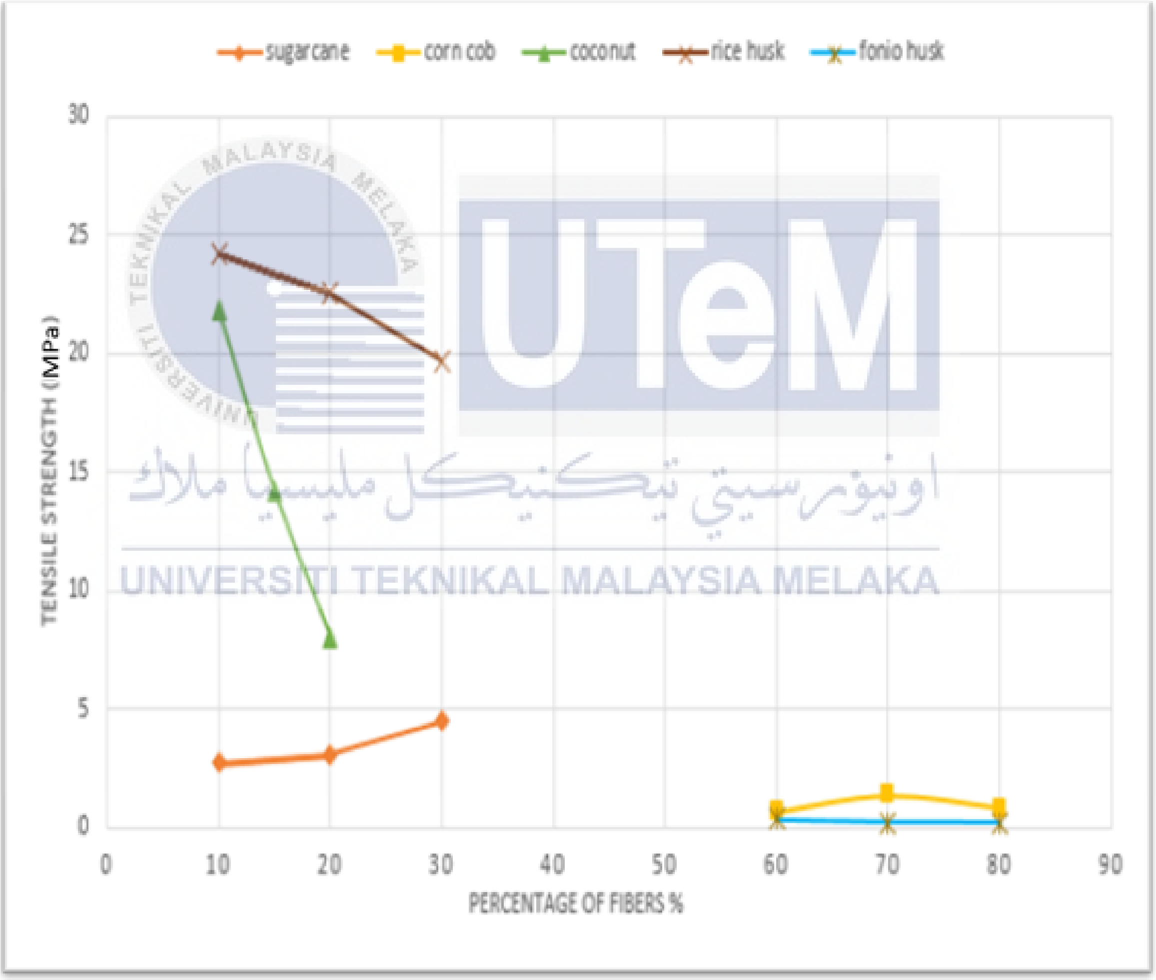

Figure 4.2: Tensile Strength (MPa) versus Percentage Fibers (%)

Figure 4.2 shows the graph of tensile strength versus percentage fibers. Figure 4.2 shows that rice husk composite has the highest value of tensile strength than the other fiber. The tensile strength for rice husk decreases as the content of fiber increases. The coconut composite also has the same pattern of decrease value of tensile strength with rice husk composite. For sugarcane composite, it shows the rising amount of tensile strength as the percentage of fiber increases. The maximum value of tensile strength hits when the fiber content at 30%. The fonio composite also has an increased tensile strength but with a small value difference. Fornio composite has the lowest value of tensile strength. For the corn cob composite, the result of tensile strength reaches its maximum value at 70% of fiber content, and the value of tensile strength reduction obtained at 80% of fiber content.

The rice husk composite has a maximum value of 10 percent of fiber content and decreases when the fiber content increases. The drop in the value of tensile strength is due to poor adhesion between polypropylene and rice husks so that the tension does not transfer between the two phases effectively (Frounchi et al., 2007). It shows that the composite mixture for ratio 1:9 fiber and resin is the best composition for this composite. This result also applies the same on the coconut composite. For the sugarcane composite, the pattern graph shows the rising value of tensile strength. It can conclude that with the higher sugarcane fibers content, the total area of contact between fibers and polypropylene resin is higher and make it have stronger bonding. They both have the lower tensile strength for the corn cob and fonio husk, which is below 2 MPa. It is because they have a low content of binder, which is 40% and below. It makes the fiber does not have enough binders to attach each other and have low bonding when fabricating the composite.

4.4 THERMAL CONDUCTIVITY

The thermal conductivity test was carried out with the Armfield Heat Conduction machine. In this test, the fiber that will be compared are sugarcane bagasse, sisal leaves, coconut, corn cob, and rice husk. Table 4.3 shows the data of thermal conductivity from various types of fibers. The formula used to calculate the thermal conductivity from the previous study is explained in Equation 4.1, 4.2, 4.3, and 4.4.

$$k = \frac{Q\,(\Delta L)}{A\,(\Delta T)} \quad (4.1)$$

$$\Delta T = Thot - Tcold \quad (4.2)$$

$$Thot = T3 - \frac{T2 - T3}{2} \quad (4.3)$$

$$Tcold = T6 + \frac{T6 - T7}{2} \quad (4.4)$$

where the fixed value,

Power (Q) = 0.855 Watt

Radius (r): 15 mm

Area sample (A) = πr^2

= $\pi\,(15 \times 10^{-3})^2$

= $7.068 \times 10^{-4}\ m^2$

Length Sample (mm): 30 mm

Table 4.3: Thermal conductivity data

FIBER	BINDER	PERCENTAGE (%)		THERMAL CONDUCTIVITY (W/mK)
		FIBER	BINDER	
Sugarcane	Polypropylene	30	70	0.096
		20	80	0.132
		10	90	0.157
Sisal	Polyethylene	40	60	0.121
		30	70	0.103
		20	80	0.112
Coconut	Polyester	30	70	0.160
		20	80	0.142
		10	90	0.176
Corn cob	Epoxy	30	70	0.101
		20	80	0.110
		10	90	0.124
Rice husk	Polyethylene	50	50	0.071
		40	60	0.074
		30	70	0.087

Table 4.3 shows, all the thermal conductivity data of sugarcane fibers are obtained from the previous study of (Fernea et al., 2019), while the data of sisal fibers are from the prior research of (Cabral, Fiorelli, Cravo, & Savastano, 2017), for the coconut fibers the tensile test was done by (Din, Hafiz, & Rus, 2018), for corn cob fibers the tensile test was done by (Binici, Aksogan, & Demirhan, 2016) and for the rice husk fiber the data are from the previous study of (Asdrubali, D'Alessandro, & Schiavoni, 2015).

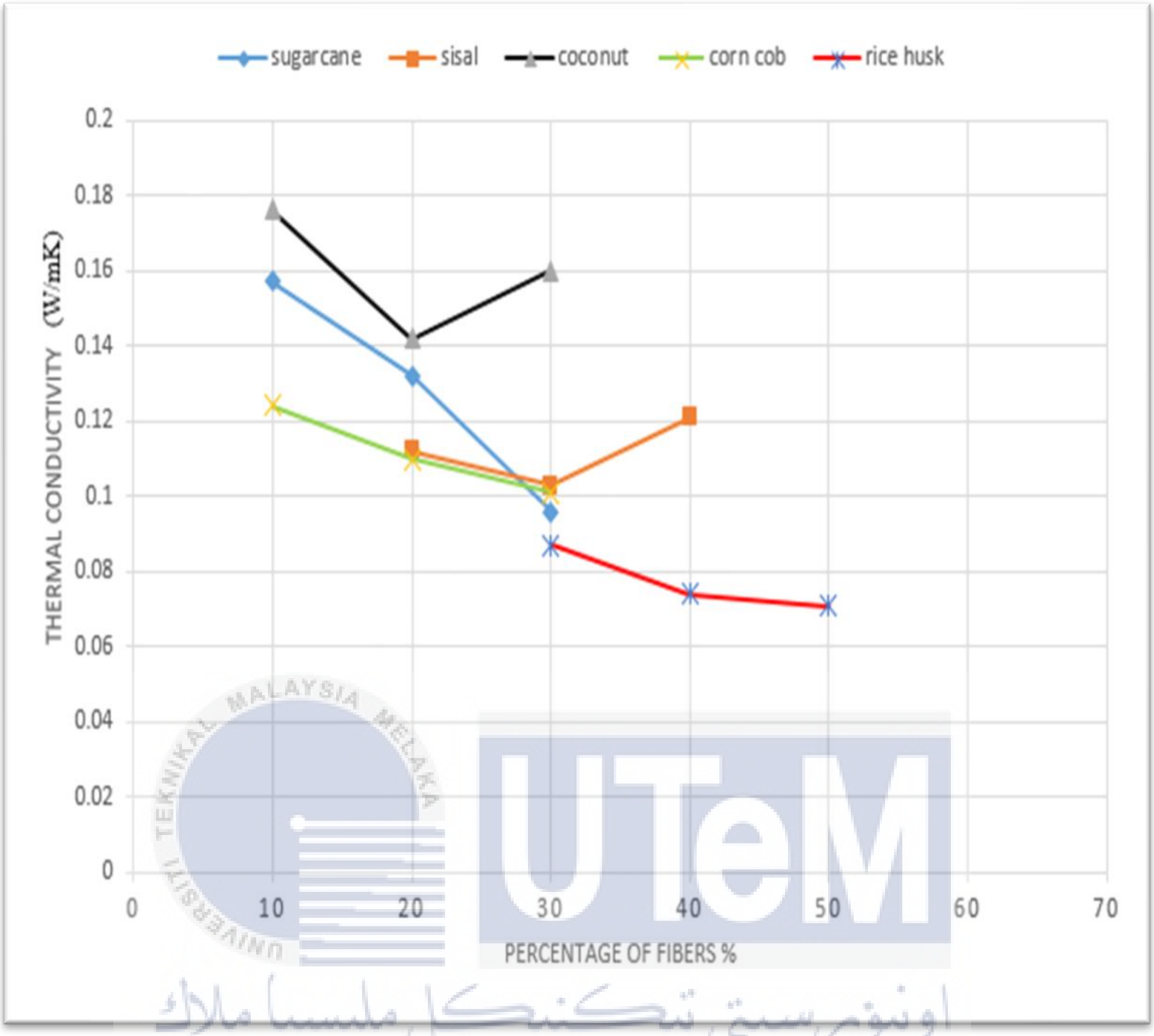

Figure 4.3: Thermal Conductivity against Percentage Fibers (%)

Figure 4.3 shows the graph of thermal conductivity against percentage fibers. It shows that the rice husk composite has the lowest thermal conductivity value, while the coconut composite has the highest value. Three composites have a decreasing amount of thermal conductivity when the fiber content is rising, which are rice husk, sugarcane, and corn cob. The sugarcane and corn cob composite hit their lowest value of thermal conductivity when the content of fiber is at 30 percent and for the coconut composite, the result of thermal conductivity reaches its minimum value at 20% of fiber content, and then, the value is rising at 30% of fiber content. The sisal leave composite also has the same graph pattern as coconut.

The results in Figure 4.3 show that the thermal conductivity value of the composite fiber was generally higher than 0.1 W/mK, below which a material is classified as good insulation material compliance to TS 805 EN 601. Besides, natural fiber is known as their low density and their high value of thermal conductivity.

The rice husk composite shows the lowest value of thermal conductivity than the other composites. It is because the rice husk appears to be good material as a polymer matrix filler since its excellent thermal stability compared to other natural fiber. According to Paiva et al., (2012), the thermal conductivity value, which is near to 0, is excellent for building thermal insulation. For the sisal, corn cob, and sugarcane composite, they hit the best thermal conductivity value at 30% of fiber content. Compared to these three fiber composite, it can conclude that the sugarcane composite has the lowest thermal conductivity value and has better thermal insulation than the others. That means sugarcane fiber could absorb most of the sun's heat better than the others before transmitting the heat to the house. It can conclude that the rice husk composite has an excellent thermal conductivity value, followed by sugarcane composite, corn cob composite, sisal leaves composite, and the last is coconut composite with the highest value of thermal conductivity among them.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

From the comparison results obtained in this study, the following conclusion can be drawn: -

- In terms of hardness testing from previous studies, the hardness test for epoxy alone can get the highest value as it decreases when mixing with banana fiber. Sugarcane particleboard gives an increasing value of hardness as the content of its fiber increases. Sugarcane fibers have a high content of lignin, which contributes to the higher measured hardness of particleboard. Overall, the sugarcane and coconut fiber is suitable for making particleboard as they have a great value of hardness.

- In terms of the tensile test from the previous studies, it can be concluded that the composite percentage of fiber 10% to 30% gives a higher value of tensile test than the composite that has a percentage of fiber 60% to 80%. It can conclude that the higher binder percentage will give the higher result of the tensile test as it can make the bonding with fiber stronger. So from the result, corn cob and fonio composite does not look suitable for making particleboard.

- In terms of thermal conductivity from the previous studies, rice husk and sugarcane have obtained the value of thermal conductivity, k below 0.1 W/mK. Based on TS 805 EN 601 standard, it requires a thermal conductivity value of lower than 0.1 W/mK in to get the excellent material as thermal insulator particleboard. But for overall, all the previous results is suitable for making good thermal insulator particleboard.

Finally, the most significant finding from this study is that the waste materials that generate environmental degradation should be used to produce the organic content that is economically suitable for making great particleboard.

5.2 RECOMMENDATION FOR FUTURE WORK

Based on the understanding and preliminary knowledge, some recommendations that may help future work experiments a better results.

a) The fiber needs to undergo chemical treatment implementation such as NaOH, silane coupling agent, and others to increase the bonding and structure of the fibers with the mixture composition.
b) Making the variety of fiber percentage content to get to know which is the best percentage of that fiber content can be used to fabricate the particleboard.
c) The mechanical testing should be done more experiments to get the more properties of that particleboard. Some of the experiments that should be done for the future are the flexural test, impact test and Scanning Electron Microscopy (SEM).

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APPENDIX 1

FABRICATION SUGARCANE PARTICLEBOARD PROCESS