EFFECT OF DIFFERENT TYPES OF BANANA PLANTS FIBRES ON THE PHYSICAL, MECHANICAL AND THERMAL PROPERTIES OF AGAR BASED COMPOSITES

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DECLARATION

I hereby declare that I have conducted, complete the research work and written the dissertation entitled "Effect Of Different Types Of Banana Plants Fibres On The Physical, Mechanical And Thermal Properties Of Agar Based Composites". I also declared that it has not been previously submitted for the award for any degree or diploma or other similar title of this for any examining body of University.

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Date: 22 June 2018

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LIST OF SYMBOLS

℃	Degree Celcius
mm	Milimeter
g	Gram
mm/ min	milimeter per minute
mm^2	square milimeter
μm	Micrometer
mg	Miligram
%	Percentage
W	Watt
Pa	Pascal
cm	Centimeter
J	Joule
T_m	Melting temperature
T_g	Glass transition temperature
kV	kilovolt

LIST OF ABREVIATIONS

SEM	Scanning Electron Microscope
TGA	Thermo Gravimetric Analysis
DSC	Differential Scanning Calorimeter
FTIR	Fourier Transform Infrared
ASTM	American Standard for Testing and Material
BFS	Banana Stem Fibre
HDPE	High Density Polyethylene

KESAN GENTIAN DARI JENIS POKOK PISANG BERBEZA TERHADAP SIFAT-SIFAT FIZIKAL, MEKANIKAL DAN TERMA KOMPOSIT BERASASKAN AGAR

ABSTRAK

Dalam kajian ini, tiga jenis gentian batang pisang iaitu Pisang Awak, Pisang Nangka, dan Pisang Emas telah digunakan beserta agar yang berlainan komposisi iaitu 10%, 20%, 30% dan 40% untuk menghasilkan komposit. Sifat komposit seperti fizikal, mekanikal, sifat terma, dan permukaan morfologi telah dijalankan bagi proses penyelidikan ciri – cirinya. Gentian pisang dan agar telah dikisar sebelum digunakan untuk meghasilkan komposit. Dua bahan ini digaulkan bersama agar sebati dan sama rata untuk mendapatkan penyebaran terbaik antara agar dan gentian pisang tersebut. Komposit tersebut dihasilkan menggunakan mesin mampatan dan dibiarkan pada suhu 180℃ selama 25 minit. Ujian FTIR telah dijalankan ke atas ketiga tiga jenis gentian pisang tersebut termasuk agar yang berada dalam keadaan serbuk untuk mengetahui kumpulan berfungsi yang ada pada bahan tersebut. Ujian penyerapan air dijalankan pada suhu bilik ke atas setiap komposit menggunakan air suling. Daripada keputusan kajian, kebanyakan komposit menunjukkan penyerapan air yang tinggi pada kandungan agar yang tinggi. Untuk sifat mekanikal, ujian seperti kekuatan tensil dan ujian hentaman telah dijalankan. Ujian haba juga telah dijalankan ke atas komposit menggunakan Kalorimetri Pengimbasan Kebezaan (DSC) untuk mengetahui suhu peralihan kaca dan suhu leburan, manakala Analisis Gravimetri Terma (TGA) digunakan untuk mengetahui corak penguraian komposit. Apabila kandungan agar meningkat kepada 40%, suhu penguraian komposit juga meningkat kecuali Pisang Emas. SEM digunakan untuk melihat morfologi permukaan patah komposit selepas ujian impak. Pemerhatian seperti lubang kecil, liang, dan penarikan keluar gentian dapat dilihat daripada ujian ini yang memberikan indikasi terhadap interaksi antara agar dan gentian.

EFFECT OF DIFFERENT TYPES OF BANANA PLANTS FIBRES ON THE PHYSICAL, MECHANICAL AND THERMAL PROPERTIES OF AGAR BASED COMPOSITES

ABSTRACT

In this work, three types of banana stem fibres which were from Pisang Awak, Pisang Nangka, and Pisang Emas were prepared with different compositions of agar that are 10%, 20%, 30% and 40% to form composite. The properties such as physical, mechanical, thermal, and surface morphology were characterized. Banana fiber and agar were grinded in order to produce the composite. These two components were mixed homogenously and evenly in order to get better distribution of the agar with the fibre. The composites were produced using hot press machine at temperature of 180℃ for 25 minutes. FTIR test was conducted on each types of banana fibres and agar which were in powder form to determine their functional group. Water absorption test was conducted using distilled water at room temperature. From the result, most of the composites showed the high value of water absorption as high content of agar increase. For mechanical testing, the tensile and impact strength were done to investigate the properties of the composite. Thermal properties of the composite also have been investigated by using by using Differential Scanning Calorimetry (DSC) to determine the melting temperature (T_m) and glass transition temperature (T_g) meanwhile Thermogravimetric Analysis (TGA) was used to determine the decomposition pattern of the composite. As the content of agar increase to 40%, decomposition temperature increase except for Pisang Emas composite. The scanning electron microscope (SEM) was used to analyze the fracture morphology of the surface that was taken from impact test. From the SEM test, it can be observed that characteristic such as void, porosity and fibre pull out were presence on the fracture surface of the composite which give indication of the interaction between agar and fibre.

CHAPTER 1

INTRODUCTION

1.1 Natural Fiber Composite

The usage of polymer in various applications have replace many of the conventional metals / materials over the past few decades. The ability offer by the polymer make it usage are advantageous over the conventional materials. The ease of processing, productivity and the construction are the significant advantages provide by the polymer. In most of the application, the properties of the polymers are modified using fillers and fibers to suit the high strength / high modulus requirement. Fiber reinforced polymers offer advantage over other conventional material when specific properties are compared.

Natural fibers have as of late pulled in the consideration of researchers and technologists on account of the preferences that these fibers give over traditional support materials and the improvement of characteristic fiber composites has been a subject of enthusiasm for as long as couple of years (Dixit et al., 2017). These natural fibers are low-cost fibers with low density and high specific properties. These are biodegradable and nonabrasive, unlike other reinforcing fibers such as carbon fibre, glass fibre and aramid. Also, they are readily available and their specific properties are comparable to those of other fibers used for reinforcements. However, certain drawbacks such as incompatibility with the hydrophobic polymer matrix, the tendency to form agglomerates during processing and poor resistance to moisture greatly reduce the potential of natural fibers to be used as reinforcement in polymers.

Natural fiber include coir, jute, bagasse, cotton, bamboo, hemp. Natural fibers come from plants. These fibers contain lignocellulose in nature. Natural fibers are eco-friendly; lightweight, strong, renewable, cheap and biodegradable. The natural fibers can be used to reinforce both thermosetting and thermoplastic matrices. Thermosetting resins such as epoxy, polyester, polyurethane, phenolic are commonly used composites for higher performance applications. They provide sufficient mechanical properties in particular stiffness and strength at acceptably low price levels. Recent advances in natural fiber development are genetic engineering. The composites science offer significant opportunities for improved materials from renewable resources with enhanced support for global sustainability. Natural fiber composites are attractive to industry because of their low density and ecological advantages over conventional composites. These composites are gaining importance due to their non-carcinogenic and bio-degradable nature. The natural fiber are widely used in building and construction packaging, automobile and railway coach interiors and storage devices due to it cost effectiveness (Mukhopadhyay, 2009).

The application in load bearing that are commonly used glass fiber as reinforcement which are more costly are able to be replaced by the natural fiber composite (Sukim et al., 1995). Natural fibers have the advantages of low density, low cost and biodegradability. However, the main disadvantages of natural fiber composite are the relative high moisture absorption. Therefore, chemical treatments are normally done to modify the fiber surface properties.

Since the plastics are soft, flexible and lightweight in comparison to fibers, their combination provides a high strength-to-weight ratio to the resulting composite. A major disadvantage of cellulose fibers is their highly polar nature, which make them incompatible with non-polar polymers. Also, the poor resistance to moisture absorption makes the use of natural fibers less attractive for exterior applications. The interfacial compatibility between the polymer and fiber will determine the properties of the composite itself (Nair and Thomas, 1996).

The tensile and flexural failure surfaces of the samples have been examined by Scanning Electron Microscopy (SEM), to understand nature of failure, matrix adhesion, fiber breakage and pull out. Fundamental information regarding the thermal stability of the composites material to be processed can be obtained from thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) (Khaddami et al., 2004). TGA is commonly used to measure the change in weight of the material as a function of temperature in an inert atmosphere or in the presence of air or oxygen.

1.2 Problem Statement

Basically, the properties of natural fibers such as banana are varied from each types of banana plants. The components that presents in each types of banana fibers may varied from each banana plants. This could affect the properties of the banana fibers itself. Depending on the required properties from the banana fibers, the suitable banana fiber that meet the requirement to desired properties will be the best banana fiber to be used.

In order for the natural fiber that is banana fiber to be used as composite, agar was introduced and used together with banana fiber as a binder in order to bind and wet the banana fiber firmly and properly. Without agar, banana fiber not be able to bind properly to each other which lead to poor properties. Thus, the amount of agar that used together with the banana fiber may give effect towards the properties in term of physical, mechanical and thermal properties of composites.

At present, due to uncertain conditions in the shortage and the cost of petroleum, and it by products, there is a need to search for its alternate, which is nothing but natural. In recent years the vegetable/plant fibers proves itself as an alternative fiber to its synthetic counterpart. Natural fibers are cheaper, bio-degradable and have no health hazard. Furthermore natural fiber reinforced fibers are seen to have good potential in the future as a substitute. Natural fibers are extracted from various plant parts and classified accordingly.

One of the major environmental problems we are facing today is the plastic waste problem. The tremendous production and use of plastics in every segment of our life has increased the plastic waste in huge scales. The waste disposal problems, as well as strong European regulations and criteria for cleaner and safer environment, have directed great part of the scientific research to eco-composite materials that can be easily degraded or bio assimilated.

It is interesting to note that natural fibers such as jute, coir, banana, sisal, etc., are abundantly available in developing countries like India, Sri Lanka, and some of the African countries but are not optimally utilized. At present these fibers are used in a conventional manner for the production of yarns, ropes, mats, and matting as well as in making articles like wall hangings, table mats, handbags, and purses. Fibers such as cotton, banana, and pineapple are also used in making cloth in addition to being used in the paper industry.

Natural fibers have recently attracted the attention of scientists and technologists because of the advantages that these fibers provide over conventional reinforcement materials, and the development of natural fiber composites has been a subject of interest for the past few years. These natural fibers are low-cost fibers with low density and high specific properties. These are biodegradable and nonabrasive, unlike other reinforcing fibers. Also, they are readily available and their specific properties are comparable to those of other fibers used for reinforcement.

In field of industrial such as food technology and pharmaceutics, agar – agar which classified as polysaccharides that fall into class of natural polymers are now getting an expanding consideration. This is due to the nature that provide by the agar – agar which are renewable sources, abundant, biodegradable material, non – toxic which create the ability for this agar – agar to replace conventional polymers in various application.

1.3 Research Objectives

I. To study the effect of different types banana fiber used on the physical, mechanical and thermal properties of banana fiber/agar composite.

II. To study the effect of agar loading on the physical, mechanical and thermal properties of banana fiber/agar composite.

III. To study the fracture surface of banana fiber/agar composite by using scanning electron microscope (SEM).

1.4 Scope of Work

The main materials used for producing this banana fiber composite are banana fiber and agar. These main materials make the system of natural fiber composite. The banana fiber take a role as reinforcement and the agar which is natural polymer function as a binder for binding together with banana fiber. The banana fiber which was collected from three different types of banana plant undergone milling process to remove the water inside the fiber for ease of drying inside the oven followed by grinding process and sieving to form banana powder. Same as banana pseudostem, agar – agar also undergo grinding process.

Both of the banana fiber and agar powder were used in compounding process for making banana fiber/ agar composite in the form of fibreboard where agar was applied on the banana fiber. The fiber were layered perpendicularly. The size of mould that was used to make the composite is 200 mm × 200 mm × 3.5 mm. The mould was then pressed using hot press for the production of the product which was fibreboard. The banana fiber / agar based composite which has formed composite was then trimmed and cut to undergo water absorption, mechanical testing, and thermal analysis. The fracture surface of the composite was studied using Scanning Electron Microscopy (SEM).

1.5 Chapter Review

1.5.1 Chapter 1

This chapter will discuss the overall view and picture of main idea of the project. This chapter also describe about the natural fiber and its application in the world. The main problem to conduct this project is about the banana stem fibre and the agar – agar that used as polymer matrix in the composite. This chapter also introduced about the importance of the natural fiber and the application of natural fiber and the used of agar – agar in food industry. The objective of this project are also stated in Chapter 1.

1.5.2 Chapter 2

In this chapter, a clear explanation on the literature review on the related topic that is suitable and relevant in this project. This Chapter 2 consist of information of literature review which included natural fiber composite, component and composition in natural fiber, composite system, matrix, thermosetting composite, agar properties, banana plant, treatment of banana fiber, testing on natural fiber, and the application of natural fiber.

1.5.3 Chapter 3

All the methods that were used in this project are discussed in this chapter. The process that begin from the banana pseudostem that are collected until composite were produced are discussed in this chapter. The process to convert the raw material which is banana stem to short fiber involve the process such as drying of banana stem, milling of banana fibre and grinding of banana fibre are discussed in this chapter. Same goes to the process to convert the agar – agar to form powder that involved the drying and grinding process. The method that was used to fabricate the composite was hot press by compressing the compound using mould at higher temperature.

1.5.4 Chapter 4

This chapter will post all the final results that were obtained from each of the testing that are conducted such as water absorption test, mechanical testing and thermal analysis. The data that obtained are analysed and discussed for the characterization of different types of banana fiber from three types of banana plants. This chapter also contain a few graphs and the micrographs of surface morphology of fracture composite’s surface.

1.5.5 Chapter 5

This is the final part that concludes all the results and finding that are relevant to the project based on the objective of the project that have been decided earlier of the Chapter 1, and there are a few recommendations that are suggested and proposed to improve the project in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Composite

Composite are generally composed of two phases, one called the continuous or matrix phase that surround the second discontinuous or dispersed phase (Carraher, 2007). There are varieties of polymer- intense composite that can be classified as shown in Figure 2.1. Many of these composite groups are used in combination with other material including different types of composite and like type of composite except differing in orientation.

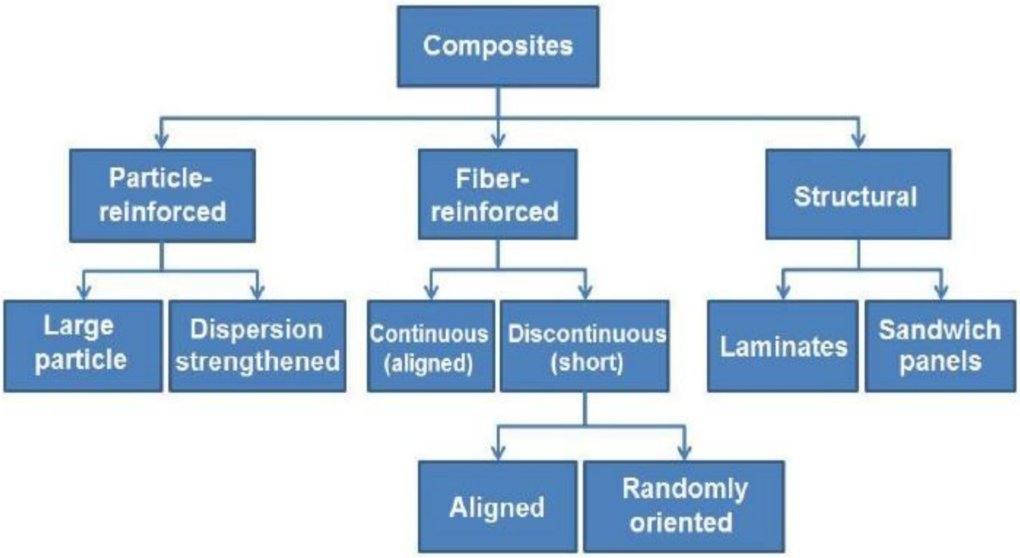

Figure 2.1 : Classification of composite. (Carraher, 2007).

The combination of plastic matrix and reinforcing fiber gives rise to composite having the best property of each component. Composites with the high strength- to weight ratio are able to be produced from the combination of plastic that have characteristic such as soft, flexible, and lightweight compared to the fiber. For natural fiber composite, a few plastics has been recognised to be used as matrix (Nair et al., 1976). The commonly used thermoset are such as polyester, epoxies, and phenolic. Thermoplastic that are commonly used are, Polyethylene (PE), Polystyrene (PS), and Polypropylene (PP) (Nair, 1976).

There is an increase applications that used natural fiber in composite due to few factors such as choice of the fiber and matrix pair, the fabrication method and manufacturing procedures, the final application envisaged, and the fiber surface treatment (Bledzaki et al., 1999).

There have been reported that in polymer matrices system, it is able to use banana fibers as reinforcing components (Sapuan et al., 2006) and it is able to be used as an alternative reinforcement in the composite material which has been pointed out by researchers. In polyester resin, it was found that it could act as a good reinforcement by banana fiber (Mariatti et al., 2005).

Depending upon the nature and origin of the reinforcement as well as the polymer matrix, there are two different categories and types of polymer composites which are totally renewable composites and partly renewable composites (Thakur and Singha, 2013). Usually, the reinforcing materials and source of the matrices itself are come from bio renewable resources for the totally renewable polymer composite materials (Thakur and Singha, 2013). In partly renewable composites, only one component is from bio renewable resources such as a polymer matrix from bio renewable resources and a reinforcement from non - renewable resources or a polymer matrix from synthetic resources and a reinforcement from bio renewable resources.

A study was conducted on the use of woven banana fibers as reinforcement in epoxy (Sapuan et al., 2006). Tensile test result showed that the woven kind of reinforcement has better strength and the same was confirmed using Anova technique.

The usage of the banana fiber reinforced with polymer matrices composite with reference to physical properties, structure, and application was reviewed by Venkateshwaran and ElayaPerumal, (2010).

2.2 Introduction to Natural Fiber

Natural fibers are the continuous filament or discrete elongated pieces, similar to piece of thread, and they can be spun into the filament, thread, or rope. They can be used as a component in a composite material. They can also be metted into sheet to make products such as paper or felt. There are two types of fibers: natural fiber or man – made or synthetic fiber. Fibers that are derived naturally are mainly come from three main sources which are animals, minerals, and vegetables. That particular natural fiber are obtained from specific part of vegetable plant and provided by nature in ready – made form. This also included for other type of fibers which are from animal such as wool and silk, cellulose fiber such cotton and linen, and mineral fiber asbestos (Mohanty et al., 2000).

In today's modern world the need for more efficient material is very significant for the development of a new product. As the properties and ability given by this composite that consist of a strong load carrying material embedded in weaker material, thus make the composite play a major role. For the structural load application, definitely it require reinforcement that has the ability to provide strength and rigidity to support it. For the structural purpose, polymer matrix composite are widely used, but due to inadequate mechanical properties of polymer itself contribute to disadvantage (Uma et al., 1995). In view of its versatility, they are used in aerospace, automobile, electrical, construction, and sports equipment industries.

The natural fiber reinforced polymer composites (NFRPC), (simply natural fiber composites (NFC)), became recently highly valuable materials. In this type of materials, natural fibers (such as hemp, sisal, jute, kenaf, flax, etc.) are used as reinforcing material (fillers) for polymer-based matrices. Due to the high cost of the petroleum resources, together with the current government encouragement for the new regulation and legislation for the environmental aspect toward the sustainability scope based on current situation which are, growing of ecological, social, and economical awareness, there have been enhanced optimum utilization of natural resources (Kalia et al., 2011).

The ability that display by the natural fiber which is potential environmentally friendly materials that can become indispensable components of polymers for various applications make it are being visualized compared to other biopolymer – based materials (Thakur et al., 2013). The characteristics that make the natural fibre is more advantage compared to synthetic fibers such as glass fibers, aramid fibers, and carbon fiber, is due to it renewable nature that display by various kinds of natural fibre (e.g., Hibiscus sabdariffa, henequen, Grewia optiva, sisal, pine needles, flax, jute, kenaf, coir, and many others) (Fernandes et al., 2013).

Due to the excellent properties exhibit by the natural fiber such as as high specific strength, low weight, low cost, fairly good mechanical properties, non-abrasive, eco-friendly and bio-degradable characteristics, this make the natural fiber be as an alternative reinforcement for fiber polymer composite (Sanjay et al., 2005). Application such be as a resources for industrial materials has been shown by many of plant fiber which are sisal, coir and banana (Satrayana et al., 1990). Tables 2.1 show the physical and mechanical properties some natural fibers.

Table 2.1: Physical and mechanical properties of some fibers (Satrayana et al., 1990).

Fibers	Width or diameter (μm)	Density (kg/m^3)	Cell l/d ratio	Microfi-brillar angle (degree)	Initial modulus (GPa)	Ultimate tensile strength (MPa)	Elongation at break (%)
Coir	100 - 450	1150	35	30 – 40	4 – 6	106 – 175	17 – 47
Banana	80 – 250	1350	150	10± 1	7.7 – 20.0	54 – 754	10.35
Sisal	50 -200	1450	100	10 – 22	9.4 – 15. 8	568 – 640	3 – 7
Pineapple leaf	20 – 80	1440	450	8 – 14	34.5 – 82.5	413 – 1627	0.8 – 1
Palmyra	70 - 1300	1090	43	29 - 32	4.4 – 6.1	180 – 215	7 – 15

Natural fibers that are derived from plants are grouped into three types: seed hair, bast fiber, and leaf fiber, depending upon the sources. Some example are cotton (seed hairs), ramie, jute and a flax (bast fiber). Of this fiber, jute, ramie, flax, and sisal are the most commonly fiber used for polymer composites. Natural fiber in the form of wood flour have also been often used for preparation of natural composite. Recently, the preservation of the natural resources and the strict environmental regulation have forced the composite industrial to find alternative fiber reinforcement and resin system that are eco - friendly to produce compatible composite. Therefore, the need for natural fiber reinforced composite has never been as prevalent as it currently is. The properties that exhibit by the natural fiber compared to synthetic fibers such as glass and carbon are renewability, biodegrability, abundance, cost saving, and low specific gravity (Sapuan et al., 2006).

The ability of the natural fiber to perform as acoustic and thermal insulator, and exhibit bulk density id due to their hollow and cellular nature (Mohanty et al., 2003).

Depending on their performance when they included in a polymer matrix, lignocellulose reinforcement can be classified into three categories: (1) wood flour particulate, which increase the tensile and flexural modulus of the composite, (2) fiber of higher aspect ratio that contribute to improve the composite modulus and strength when suitable additives are used to regulate the stress transfer between the fiber and the matrix, (3) long natural fiber with the highest efficiency among the lignocellulose reinforcement (Pothan et al., 2003).

2.3 Composition and components of natural fiber

Cellulose, hemicelluloses, pectin and lignin are the major components that present in the natural fibers. The composition of this components are varies for each types of natural fiber. This variation can also be effected by growing and harvesting conditions. The hydrophilic nature of the natural fiber are mainly come from cellulose which are semi crystalline polysaccharide. Hemicellulose is a fully amorphous polysaccharide with a lower molecular weight compared to cellulose. The properties such as being partially soluble in water and alkaline solutions is due to the amorphous nature of hemicelluloses (Bledzki et al., 1999). Pectin, whose function is to hold the fiber together, is also a polysaccharide, like cellulose and hemicellulose. Same as hemicellulose which mainly consisted of aromatic, lignin component also exhibits that particular aromatic ring which make both components as amorphous polymer and due to this structure the little water absorption are due on the structure of lignin (Saheb and Jog 1999).

A mature flax cell wall consists of about 70 –75% cellulose, 15% hemicellulose, and pectic materials. Cellulose is a natural polymer with high strength and stiffness per weight, and it is the building material of long fibrous cells. Selective removal of noncellulosic compounds constitutes the main objective of fiber chemical treatment. Both the hemicellulosic and pectin materials play important roles in fiber bundle integration, fiber bundle strength, and individual fiber strength as well as water absorbency, swelling, elasticity, and wet strength. The production of individual fibers without the generation of kink bands will generate fibers with much higher intrinsic fiber strength, which is very useful for composite application (Williams and Wools, 2000)

The cellulose of natural fiber contain different natural substances such as lignin and waxes. The lignin structure that exist in the natural fiber are bonded together with the other component that use cellulose. Physical properties of natural fibers are usually influenced by the chemical structure such as cellulose content, degree of polymerization, orientation and crystallinity, which are affected by the conditions during growth of plant as well as extraction method used. The variation for each types of fiber are mainly due to the different part fibers are taken from the plant, location of particular plant growth, and also the quality of the plant. (Mukherjee and Radhakrinan, 1972).

Bast fibers, like banana, are complex in structure. They are generally lignocellulosic, consisting of helically wound cellulose microfibrils in amorphous matrix of lignin and hemicellulose. The cellulose content serves as a deciding factor for mechanical properties along with microfibril angle. A high cellulose content and low microfibril angle impart desirable mechanical properties for bast fibers. Lignins are composed of nine carbon units derived from substituted cinnamyl alcohol; that is, coumaryl, coniferyl, and syringyl alcohols. Lignins are associated with the hemicelluloses and play an important role in the natural decay resistance of the lignocellulosic material. From elemental analysis, it is able to determine the composition of banana pseudostem (Bilba et al., 2007).

Cellulose and its derivatives such as cellulose acetate, provide good examples of the influence of crystallinity on solubility. The large number of hydroxyl groups in cellulose would increase the affinity of polymer to water. The hydroxyl groups in the amorphous regions combine with water to give the relatively high moisture regain of cellulose fibers. The most suitable solvent for cellulose are alkaline meanwhile common solvent that are used is cuprammonium solution (Garbizu et al., 2004).

Each types of natural fibers will vary among the others for their chemical constituents. The chemical composition in Table 2.2 as well as the structure of the plant fibers is fairly complicated (Amar et al., 2005). Plant fibers are a composite material designed by nature. The fiber mainly have rigid, crystalline structure that attributed by cellulose microfibril, meanwhile the amorphous part of the natural fiber are come from lignin and hemicellulose. Most plant fibers, except for cotton, are composed of cellulose, hemicellulose, lignin, waxes, and some water-soluble compounds, where cellulose, hemicelluloses, and lignin are the major constituents (Bledzki et al., 1999).

Table 2.2: Review on the chemical composition of natural fiber (Sapuan et al., 2006).

Constituents	**Percentage**
Cellulose	31.27 ± 3.61
Hemicellulose	14.98 ± 2.03
Lignin	15.07 ± 0.66
Extractives	4.46 ± 0.11
Moisture	9.74 ± 1.42
Ashes	8.65 ± 0.10

The components such as cellulose, hemicellulose, lignin, waxes, and several water-soluble compounds are primarily present in almost of the natural fiber, except for cotton (Singha and Takur, 2008). The presence of the hydrogen bonds and other linkage in the cellulose are relatively due to the amount of cellulose in given fiber which determine the strength and stiffness of the fiber (Thakur and Singha, 2011). A number of factors affect the overall properties of a particular fiber, starting from different stages of production up to final processing.

2.4 Matrix

Matrix by definition is a continuous phase that filled free volume uncovered by filler. Matrix is divided into two major groups known as thermoset and thermoplastic. Generally, matrix act as a glue to hold filler/ fiber together and protect the filler/ fibres from mechanical and environmental damage. In composite system, matrix plays a role as a medium to transfer stresses through the fiber – matrix interface to the reinforcement or filler. In case natural fiber filled polymer composite, the incompatibility between the composites components resulted in poor stress transfer from matrix phase and incorporated filler. As consequences, the composite will fail prematurely (Franco and Gonzales, 2005).

One or more discontinuous phases therefore, are embedded in a continuous phase to form a composite. The reinforcement part which known as discontinuous phase is different from the continuous phase which attributed by the matrix due to the discontinuous phase is usually harder and stronger. The materials such as polymer, metal and ceramic may serve as matrix. When the matrix is a polymer, the composite is called polymer matrix composite (PMC). Fibre that exhibit high strength and modulus are known as fibre reinforced polymers (FRP) which mostly bonder to matrix with distinct interface between them. In this form, both fibres and matrix retain their physical and chemical identities. In the composite, role of fiber is as load carrying members, while the principle of the matrix matrix keeps them at the desired location and orientation, acts as a load transfer medium between them, and protects them from environmental damages (Kamani et al., 1997).

The properties of each component will contribute to increase in properties of material such as strength when there are combination between two or more material compared when using only one material alone (Thakur, 2013). The performance and properties of the overall composite material depend on the matrix, which is the polymer in composite material (Ramanaiah and Ratna Prasad, 2011).

The role of the matrix in a fibre reinforced composite is to transfer the load to the stiff fibres through shear stresses at the interface. This process requires a good bond between the polymeric matrix and the fibres. Poor adhesion at the interface means that the full capabilities of the composite cannot be exploited and leaves it vulnerable to environmental attacks that may weaken it, thus reducing its life span. Insufficient adhesion between hydrophobic polymers and hydrophilic fibres result in poor mechanical properties of the natural fibre reinforced polymer composites. Process such as physical and chemical treatment may decrease the hydrophilic nature the matrix (Luo and Netravali, 1999).

Good adhesion and bonding between the fiber and matrix will cause higher interaction between these two phase to occur, thus once the force exerted on that composite, stress will be effectively transferred from the matrix to the particles (Hsuesh, 1987); and this condition will cause a good contribution toward the strength of the composite itself. Addition of the particle may cause reduction in strength and this occur for poorly bonded micro-particles (Dekkers and Heiken, 1993). The property such as poor resistance to crack growth is example of the drawback of using of thermosetting resin as matrix in the composite (Moloney et al., 1987).

Fiber matrix adhesion and its relation to composite properties have been the subject of continuing study ever since the birth of composite materials in the early 1960's. At first, 'acceptable' adhesion between fiber and matrix was a 'necessary' criterion for producing a composite with 'acceptable' mechanical properties. The choice of commercial composite materials was limited and the level of fiber-matrix adhesion was considered to be a secondary factor. Indeed many of the early micromechanical attempts at describing composite behavior relied on composite materials with an implicitly high level of fiber-matrix adhesion for experimental verification of these models. Many major issue has been identified in the processing of the natural fiber composite. One major issue is the lack of perfect bonding between the fibre and the matrices, which ultimately lead to the debonding. Other than this the moisture uptake is another problem. Fiber – matrix adhesion is strongly dependant on the thermodynamics and the chemical state of the fiber surface.

The incorporation of hydrophilic natural fibers in polymers leads to heterogeneous systems whose properties are inferior due to lack of adhesion between the fibers and the matrix. Thus the treatment of fibers for improved adhesion is a critical step in the development of such composites. The treatment of the fibers may be bleaching, grafting of monomers, acetylation, and so on. In addition to the surface treatment of fibers, use of a compatibilizer or a coupling agent for effective stress transfer across the interface can also be explored.By doing surface treatment on the fiber, a few properties that contribute to the characteristics of the fiber may be changed. There are surface area, surface energy, and acid – base characteristic (Maldas and Kokta, 1993).

2.5 Thermosetting Composite

The composites possess many useful properties such as high specific stiffness and strength, dimensional stability, adequate electrical properties and excellent corrosion resistance. The properties such as ease of transportability, high payload for vehicle, low stress for rotating part, high ranges for rocket and missiles, which make them attractive for both civil and defence application are due to that particular performance of the composite (Ratna, 2007).

The thermosetting composite that are dominated the composite industry are epoxy, vinyl ester, unsaturated polyester, phenolic, polyimide, cyanate, ester, and so on. The domination of this kind of thermosetting composite are because of their availability, easier to process, lower cost for equipment capital investment, and low material cost (Ratna, 2007).

The availability of the thermosetting polymers either in oligomeric or monomeric which exhibit low viscosity liquid form which make the improvement in the flow properties of that particular resin thus facilitate resin impregnation of fiber bundles and proper wetting of the fiber surface by the resin (Ratna, 2007). They are characterised by the crosslinking reaction or curing, which convert those into a three dimensional (3D) network form (insoluble, infusible). The ability of thermoset composites give better creep properties and environmental stress cracking compared to many thermoplastic such as Polycarbonate is due to the formation of this crosslink structure.

Epoxy are widely used for industrial purpose. Various application such as food can coating, and general surface coating industry and for adhesives are mainly based on the usage of the epoxy resin (Rudd et al., 1997). Typical epoxy resin cost four times as much as general purpose polyester resins and twice as much vinyl ester resin. Epoxy resin take much longer curing time compared to polyester resin although there have been introduced some fast reacting system.

The performance of the composite is determined by good adhesion of epoxies toward the substrate and this lead to the formation of strong interface with fiber (Rudd et al., 1997). Epoxies generally have shrinkage of about 3% on cure compared with up to 8% by volume for polyester and thus giving lower residual micro – stress.

Epoxy resins are the most versatile class of thermosetting polymers among the contemporary plastics. The use of epoxy resins in high performance structural materials has been increasing recently. Multifunctional epoxies are used in high performance adhesives and advanced composite matrix materials in aerospace and electronics industries. The ability of the epoxy resin toward using in a multitude application is due to the contribution of various number of curing agents that are available (Kinjo et al., 1989).

Since some of thermoset polymer matrix such as epoxy resins and unsaturated polyester are synthetic polyester and not possess biodegradability characteristic, it would be advantageous if their role as a matrix in the composite could be replaced by natural sources or natural based polymers such as agar – agar which is one example of the biodegradable polymer. Agar – agar are able to be used as binder for banana fiber.

2.6 Agar

2.6.1 Occurrence and Biological function

The word “agar” refer to member of class of galactan polysaccharides that occur as intercellular matrix material in numerous species a red seaweeds (marine algae of class Rhodophyta). They serve a function in the structure of the plant analogous too, but differing from, that of cellulose in land plants. The capability to withstand the constant pull of gravity is inherit from the rigid structure of land plants itself, meanwhile different from marine plant which need more flexible structure for the requirement of accommodating varying stress of current and wave motion (Selby and Whistler, 1993).

2.6.2 Manufacture

Agar, at the temperature of natural environment, are exist in algae as gels**,** which undergo extraction process with water thus recovered from algae at temperature above the melting point of their gel . The extraction process are able to be done on under acidic, or basic condition, the choice depend on the type of agaropyte and the qualities that desired in the product. There will be an improvement of the gel strength as undergone combination of basic treatment process (Freile - Pelegrin and Robledo, 1997), followed by the acid extraction process may be used.

The yield of the agar may be improved by the acid extraction, while the modification structure of the gelatin chain in order to improve the gelling properties of the extract is enhanced by the basic treatment (Marinho, 2001). Polyphostate has been employed as extraction aid for the more resistance of agarophytes (Matsuhashi, 1971). The lighter colour product will produce by sequestration of iron, which is the further advantage of this treatment.

By freezing process, the gelled extract able to be recovered back to agar. On subsequent thawing, much of the water and dissolved salt separate, leaving a concentrated agar gel. This follow by the drying process. The gel are squeezed in a press which will force the water out in order to concentrate the gel is an alternative method to the freeze thaw process (Marinho, 2001).

Steam explosion, a technique used in pulping and textile industries, has recently being studied as a mean for extraction and modification of industrial polysaccharides, including agar (Murano et al, 1993). The agarophyte that has been soaking in a solution of sodium carbonate, then heated at the temperature 140 ℃ to 190 ℃ for 15 s to 20 s in the autoclave and subjected to rapid decompression (1 or 2s). The extraction of the exploded algae was done with the phosphate buffer (pH 7.4). The recovered agar was similar chemical composition to that obtained by the conventional NaOH treatment except for higher nitrogen and 6-*0*-methyl-*p*-D galactose content, but was somewhat lower in melting temperature, gel strength, apparent modulus of elasticity, though comparable to commercial agar. (Lai et al., 2006).

2.6.3 Chemical composition and covalent structure

Agar are linear polysaccharides made up of alternating B (1, 3) and A (1,4) linkage galactose residue. The disacchrides are the repeating unit for the agar. 3, 6 anhydride are commonly presented from the (1, 4) linked residue. The differences between the agar from the carrageenans, which from other important class of the seaweed, is that the (1, 4) linked residue that present in the agar is the L – enantiomer, meanwhile in the carrageenans is the d- enentiomers (Stephen et al., 1991). In both the agar and the carrageenants the (1, 3) linked residue are D- galactose. The alternative of the disaccharides structure obtained enzymatically (using $\beta -$agarose) with the preservation of the acid – labile glycosidic bond for the anhydrosugar unit, is 1 – 3 linked and has a galatosyl unit at the reducing end; the disaccharides termed *noe* – agarobiose, and has melting point of 207 ℃ – 208 ℃. (Stephen et al., 1991)

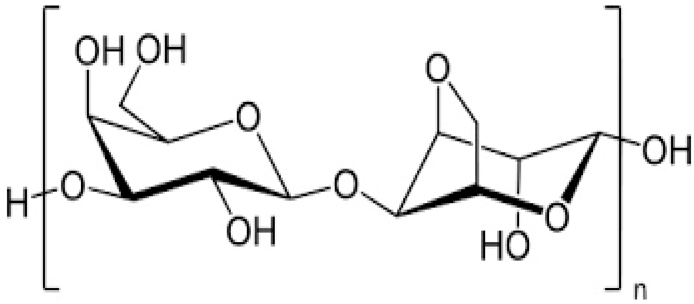

Figure 2.2 : Chemical structure of agarobiose from red algae (Stephen et al., 1991).

A component of the agar that has been recognized for a long time which is xylose (Araki et al., 1967), has received only small attention due to it structural role. In the side group of the polymer backbone chain, there are present about 18% proportion as single xylopyranosyl in agar from *Curdiea flabellate* and *Melanthalia abscissa* of the Gracilarieceae family (Furneaux et al, 1990).

2.6.4 Analysis and Properties of Agar

2.6.4.1 Analytical Method

Infrared and NMR (H and C) spectra yield useful information on the composition of agar. For infrared analysis, transmission spectrometry of dried film of the polysaccharides is preferred, but KBr pallets or reflectance spectroscopic of powdered samples are usable. Agar are characterised in the infrared region by the presence of a peak approximately 936 cm^{-1} as 3,6 – anhydro glucose , a peak at 890 cm^{-1} produced by the unsubstituted galactose, and to the diminution or absence of sulphate peak at 805, 820, 830, 835 and 1250 cm^{-1} (Sekkal et al., 1993). There is no distinguish between D- and L-enantiomers by the infrared.