PRODUCTION OF BIO RESIN FROM PALM OIL

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ABSTRACT

Nowadays, the demand for fossil fuels is quite high. But, the extensive use of fossil fuels is causing the gradual decrease of fossil fuels. Therefore, a way to get rid of widespread of using fossil fuels is by developing a new renewable source that can benefit our environment. Resin is one of the important polymeric in the chemical industry. Resins such as alkyd resins are widely used in coatings and paint industry. There are many researches about producing a resin from renewable sources such as vegetable oils. The naturally used vegetable oils in producing resin are soyabean, rapeseed, coconut, castor or linseed oils. Other than that, there are many potential vegetable oils such as karawila, nahar, rubber or safflower oil. Scientist and engineers are dedicated to find another alternative to replace using fossil fuels as the main components in resin making. This study was inspired to do a research by using palm oil as the main components in making renewable resin or bio resin. In this study, waste cooking oil was used as the main component in making bio resin. The synthesis of resin begins with alcoholysis of waste cooking oil with glycerol followed by esterification process. Then, the monoglyceride was reacted with anhydride to obtain bio resin. The resulting product which is bio resin was characterized for physiochemical properties, thermogravimetric analysis (TGA), the infrared spectrum using Fourier Transform Infrared Spectroscopy (FTIR), melting point using Differential Scanning Calorimeter (DSC). The result was compared with previous literature about producing resin from renewable material such as karawila seed oil. The expected resin is feasible in replacing synthetic resin. Thus, improvements and more research need to be made as to market the resin.

ABSTRAK

Permintaan untuk bahan api semula jadi semakin meningkat dari hari ke hari. Walaubagaimapun, penggunaan bahan api semula jadi yang berlebihan mengakibatkan sumber bahan api semula jadi berkurang secara mendadak. Oleh yang demikian, salah satu cara yang boleh digunakan untuk mengelakkan penggunaan bahan api semula jadi secara meluas ialah dengan membangunkan satu sumber yang boleh dikitar semula di mana ia mampu memberi faedah kepada alam sekitar. *Resin* seperti *alkyd resin* digunakan secara meluas dalam industri cat dan salutan. Pelbagai kajian tentang penghasilan resin melalui sumber yang boleh dikitar semula seperti minyak sayuran. Secara amnya, minyak kacang soya, minyak kelapa, minyak *kastor,* dan minyak biji rami merupakan minyak sayuran yang digunakan untuk menghasilkan resin. Selain itu, terdapat berbagai-bagai minyak sayuran yang berpotensi untuk menghasilkan resin seperti *minyak karawila, minyak nahar, minyak getah* dan *minyak safflower*. Saintis dan jurutera bertungkus-lumus dalam mencari alternatif lain untuk menggantikan penggunaan bahan api semula jadi sebagai satu komponen utama dalam penghasilan resin. Dalam kajian ini, sisa minyak masak telah digunakan sebagai komponen utama untuk menghasilkan bio-resin. Bio-resin, produk yang dihasilkan, telah dibahagikan kepada beberapa aspek kajian iaitu sifat *physiochemical,* analisis *thermogravimetric (TGA),* spektra infra merah menggunakan *Fourier Transform Infrared Spectroscopy (FTIR),* dan suhu takat lebur menggunakan *Differential Scanning Calorimeter (DSC).* Perbandingan antara hasil kajian dan hasil bacaan tentang menghasilkan resin melalui bahan yang boleh dikitar semula seperti minyak benih karawila dan telah dilakukan. Oleh yang demikian, penambah-baikan dan lebih kajian perlu dilakukan dalam usaha untuk memasarkan resin.

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BS	Banana sap
DSC	Differential Scanning Analysis
FTIR	Fourier transform infrared analysis
NMR	Nuclear Magnetic Resonance
TGA	Thermalgravimetric analysis
WCO	waste cooking oil

1 INTRODUCTION

1.1 Motivation and statement of problem

With the recent volatility in the crude oil market and its concerns over the environment. Thus, it has been a big push towards the replacement of petroleum-based resin and composites by renewable materials. The biggest advantages of renewable materials are its often available in massive quantities and much cheaper than crude oil or fossil fuels. Plus, renewable materials can produce resin that is much more biodegradable than traditional petroleum-based resin.

Resin is naturally arisen substance and created by certain type of trees that can be found in our nature. Its originally come from vegetable origin. Resins or synthetic polymers are made from two major types of monomers such as styrene and divinylbenzene by polymerization method. These monomers are used to absorb non polar organics from aqueous solution. While acrylic esters are more preferable with more polar solutes in aqueous solution (Geankoplis, 2003).

The resin begins in a high viscous state and coagulate by treatment. Commonly, resin is solvable in alcohol but not in water. The compound is sequenced in certain different ways and depending on its chemical composition and potential needs. Resin has many applications, rank from art to polymer production. Mostly, people interact with resin's products that use in a daily basis.

Natural resin originates from plants. Pine sap is one of the typical examples. It has a sharp odor of terpene compounds. Pine sap is very sticky and hardens with time. Other plants also produce resins and has been used over a thousand years. Certain types of plants show alike substance called gum resin and it makes contact with water. Natural resin can be crystal clear until dark brown in color and differs in opacity and hardness. Plus, some of natural resins are highly volatile as it contains unstable compounds.

Humans in ancient times have been using plant resins for quite a long time. Usually pine pitch has been used to reserve boats, food container and even mummies. No wonder why the mummies smelling like pine. For the preservation of the body in burial, the skin was colored with a resin made from pine. By using that, the body can remain as it is for a long time. As I mentioned earlier, plant resin are not stable enough. So, that’s why today, scientist use a synthetic resin as the replacement. Moreover, some plant resin can take years to heal and there are no promises of the final product without any imperfections.

The polymerization method done to produce synthetic resin results in more stable and homogenous polymer compare with plant resin. Plus, the stability and the cheaper price make it widely used in many products such as plastics, paints, textiles etc. Normally, synthetic resins are classified into two; thermoplastic and thermosetting. Thermoplastic resin can be softened and reformed through heat and pressure and can be set in any particular shape even after being formed. Packaging films, molded food containers and cup holders are some of the biggest applications of thermoplastic resin. While thermosetting resin are softened during the forming stage and set to their final shape. Then, they are cured by introducing a curing chemical. Once it cured to its final shape, it cannot be melted or reformed again in a another shape. Polyester is the most usual type of product that also named unsaturated polyester resin. Polyester is commonly used in the textile industry because of its high strength fiber based properties. Epoxy resin is also a common type of thermosetting that mostly used in industrial and construction materials because of the high strength properties.

In 2012, the price of plastic resin is expected to continue stable around US$1, 600 per tonne because of the lower demand from the China and also a shortage of resin supply. In the month of February 2012, the price of resin had increased from US$1, 300 per tonne to US$1, 600 per tonne because of the lack of regular maintenance work carried out at resin production plants worldwide. Naphtha, the main ingredient in plastic production has also increased from US$800 per tonne in December 2011 to US$1, 100 per tonne in 2012 (David Tan, 2012).

Unfortunately, thermosetting and thermoplastic resins are bad for our environment. Many scientists and researchers nowadays are focusing more on producing more resins that are made from environmentally friendly materials. The main issues with the thermosetting or thermoplastic resins are it is very volatile, toxic and non-sustainable.

But, these resins can be replaced with a bio-resin. Bio-resin is a range of sustainable and renewable source, formaldehyde-free, that comes from natural vegetable oils such as soya bean, rapeseed or sunflower.

Renewable sources are now having the attention of scientists because of its biodegradable characteristics. Dutta et al. (2003) carried out their research about the synthesis and characterization of polyester resins based on Nahar seed oil. In India, there are variety type of growing plants and herbs. The seed in the plant is rich in oils and seems to be an alternative of petroleum resources. Nahar (*Mesua Ferrea*) is one of example of a plant that produces abundance of oil content seeds (Dutta et al., 2003). This seed is mainly found in Assam, Uttar Pradesh and Western Ghats, India. Nahar seed contains a great amount of oil and has saturated and unsaturated fatty acids and may be applied for the synthesis of polyester resins. Dutta et al. (2003) have made a few trials for exploitation of this oil into bio-diesel and medicine field. Unfortunately, until now, there is no report of utilizing of this oil in the field of polymer.

The palm oil tree (*Elaeis guineensis*) comes from West Africa, where it grows in the wild and later was refined into an agriculture crops. It was first introduced in Malaya by the British in the early 1870’s as an ornamental plant. Later, in 1917, Tennamaran Estate in Selangor was the first commercial planting took place where it becomes the foundations of the vast oil palm plantations and palm oil industry in Malaysia. The planting of oil palm increased rapidly in early of 1960’s under the government’s agricultural diversification program. This program was introduced to reduce the country’s economic dependence on tin and rubber. Then, the government introduced land settlements for planting palm oil to reduce poverty for the landless farmers and smallholders (Anthony, 2013).

Palm oil is mainly used in food products such as margarines, cooking oils, shortening etc. Its versatility in different food applications is because of its chemical composition. Palm oil is a semisolid fat at room temperature, thus, it can be easily separated into two fractions by partial crystallization in a liquid phase. To produce a good quality of edible oil, the refined product must undergo fractionation to separate oil into two fractions, olein (liquid fraction) and stearin (solid fraction). Fractionation process depends on the melting point of triaclyglycerides. In fractionation process, there are three types of processes, that are dry, solvent and detergent fractionation. Among all these types, the dry fractionation is the simplest and economical separation technique. In the dry fractionation process, the oil is partially crystallized by fractionating the melt at the desired temperature, after which the left liquid is separated from the solid fraction by using a vacuum filter or membrane filter press (Anthony, 2013).

Others facts about palm oil;

- Reddish-orange oil that extracted from the fruit
- High in saturated fat (78%)
- Can grow into the height of 60 feet
- Weighing between 10 to 25 kg with 1000 to 3000 fruitlets per bunch
- The fruitless is spherical and elongated in shape
- Oil can be extracted from both pulp and kernels (Anthony, 2013)

Cooking oil is a plant, animal or synthetic fat that are used in baking, frying, grill and the other types of cooking. Besides that, cooking oil is also being used as the food preparation and flavoring that does not involve heat, such as salad dressings, bread dips which are termed as and edible oil. Cooking oil is usually a liquid, although there are some oils that contain saturated fat such as coconut oil, palm oil and palm kernel oil which is solid at room temperature (O’Brien, 1998).

Cooking oil that has been used repeatedly may harm the humans. When the cooking oil was used repeatedly, the concentration of hydrocarbons in the oil increases and could clog and stiffen arteries that cause hypertension and also affect the liver said Dr. T Jayabalan from National Poison Centre (Unknown, 2011). Thus, recycling cooking oil is the most important matters in the environment. Nowadays, most of waste cooking oil is converted to biodiesel as an alternative energy.

With the objective of creating boundless of the use of renewable sources, the goal of my research is to create a new environmentally friendly bio-resin using palm oil and to study the characteristic of palm oil. There are many research in producing a bio-resin from vegetable oils such as soybean, sunflower and others, but, palm oil is hardly to find. Hope with the research will find a new bio-degradable source using palm oil to produce bio-resin or kick-start for others to study this research.

1.2 Objectives

The following are the objectives of this research:

- To produce a bio resin from palm oil
- To characterize the properties of bio resin

1.3 Scope of this research

The following are the scope of this research:

i) Construction of experimental for producing bio resin from waste cooking oil using alcoholysis and esterification process

ii) Experimental analysis of properties and characteristic of bio resin by its physiochemical properties, the thermal properties using TGA, the infrared spectrum using FTIR and melting point using DSC

2 LITERATURE REVIEW

2.1 Overview

This paper represents the experimental studies of bio-resin's production from palm oil and to study the characteristic of different types of oils and bio resin.

2.2 Introduction

The rapid decreasing of fossil and petroleum sources has make engineers and chemists to further their research in producing a safer, environmentally friendly and renewable sources. Vegetable oils are one of the important branches of renewable sources among all sources. This is because vegetable oils has many chances of chemical transformation and its low price make it most preferable in the industry.

2.3 Previous work on renewable resin

Bioresin has no hazardous emissions as it is a clean and efficient process. The formaldehyde-free properties reduce the risk of exposure to carcinogenic compound that can cause cancer to human and also bad for environmental health. In 2004, the International Association for Research on Cancer (IARC) has declared that formaldehyde is a human carcinogen. Bioresin also reduce the risk related to cross-linking agents such as sulphur in furan based resins and has performance characteristics comparable to traditional petrochemical resins. Moreover, it can remove the need for release agents and other processing aids such as the oil that used in fiberglass insulation production. The versatility and can accommodate a wide range of process conditions and product formulations, make it suitable for substituting a thermosetting resin. Using vegetable oils, it can create polymers with a strong intra-chain length than traditional resin. Furthermore, the costing using vegetable oil as the main component is also less and make the production more environmentally friendly.

2.3.1 Three approaches in producing renewable thermosetting resin

Research done by Ronda et al. (2012) has found three approaches in making a renewable thermosetting resin. First, the direct polymerization through the double bonds of fatty acid chain. Next, the functionalization of the triglyceride double bonds. Lastly, by using plant oil derived chemicals to produce a tailor made monomers. They used soybean and high oleoic sunflower oil as the approach of this research. Using direct polymerization of the vegetable oils is hard because they lack of active functional groups. But, the aliphatic nature and light cross-linking has made their rigidity and strength are incapable. The faults can be cured by cationic co-polymerization of natural oils with other vinyclic monomers.

The functionalization of triglyceride double bonds are made to produce more reactive functional groups such as hydroxyl, epoxy or carboxyl groups (Ronda et al., 2012). One of the most important functionalization of the C=C double bonds is epoxidation. It easily be achieved by environmentally friendly procedures such as the catalysed chemical oxidation with hydrogen peroxide (Ronda et al., 2012). Besides that, in order to achieve reactive low viscosity liquids that are free radically polymerized and copolymerized easily with other commercial comonomers, acrylation is an important way of functionalization. This is because of the high reactivity of the acrylate group. The special properties of this functional group are that it contribute too many fields of applications and suitable for use in thermosetting techniques.

The last approach is the chemical transformation of plant oils in producing a base chemicals to get monomers for polymer synthesis. For the last approach, Ronda et al. (2012) used 10-undercenoic and oleoic acid to prepare tailored monomers and polymers. This is because they are two readily available di-functional building blocks that are suitable to be used to prepare tailored monomers and polymers. The most important part is that, the design and synthesis of this tailored monomers and polymers must be carried out in an efficient and green synthetic route.

2.3.2 UV Curing Technology

UV curing technology is a technology of fast quick curing where ultraviolet light is applied to resins to cause photopolymerization (Teck and Seng, 2011). Photopolymerization process is a process of reacting a small monomer molecules together in a chemical reaction to build a big polymer chain. Nowadays, demands for sustainable bio-based raw materials have been widely growing. UV-curable palm-based resin (Cheong, Ooi, Ahmad, Yunus and Kuang, 2009), epoxidized cyclohexane derivative from linseed oil-based coating (Zou and Soucek, 2005) and Tung-oil based resins (Chittavanich, 2011) are the example of vegetable oil-based UV-curable resins.

One of the important commercial resin is alkyd resins. They are derived from a chemical reaction of polycarboxylic, polyols and fatty acids that come from vegetable oils (Parker, 1965). Alkyd resins make up to 45% of resins used in both luminous and pigmented coatings. The reason for the high demand maybe because of their versatility from varying the proportions and types of raw materials. Alkyds that are made from vegetable oils have excellent gloss and those produced with lesser amount of vegetable oils have better hardness and chemical resistance. The frequent material used in alkyd synthesis is phthalates anhydrides, glycerol and fatty acids but, there are some formulators that prefer to use vegetable oil instead of fatty acids because of the cost saving and ease handling properties of vegetable oil (Parker, 1965).

From the finding based on characterization and alkyd properties, FTIR spectrum of AlkPA and AlkAH3 are quite identical to one another, except in the region 1650 cm^{-1} because of C=C of the incorporated Maleic anhydride (MAH) as shown in Figure 1. Besides that, NMR spectrum in Figure 2 of these two alkyds confirmed that MAH has successfully introduced into the alkyd chain were at the peak of 6.8 ppm, it was corresponded to –OOC-CH=CH-COO- protons (Teck and Seng, 2011). The FTIR peak absorbance at 1650 cm^{-1} was adjusted using peak at the 1440 cm^{-1}. Despite that, the actual amount of –CH=CH- assimilate is lower than the calculation amount because of the small amount of crosslinking takes place during the synthesis (Teck and Seng, 2011).

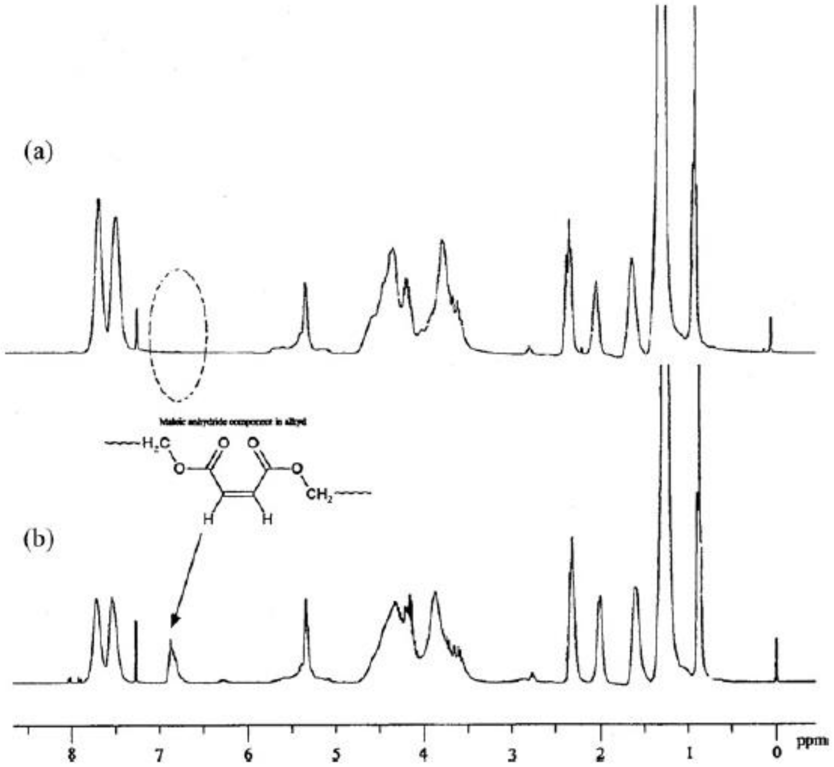


Figure 2-1: NMR spectra of AlkPA and AlkAH3

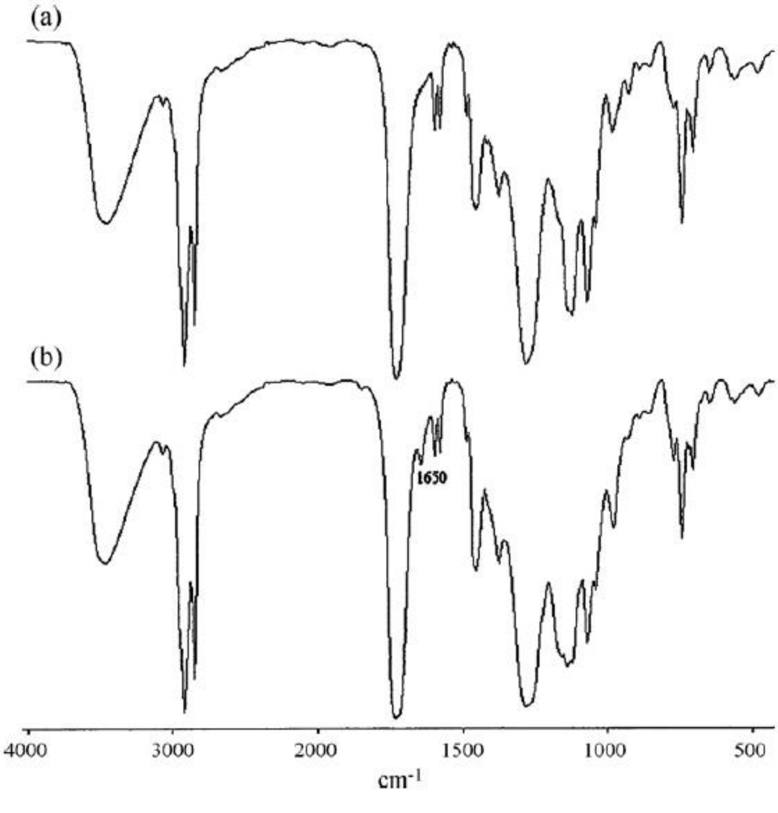


Figure 2-2: FTIR spectra of AlkPA and AlkAH3

From Figure 2-1, the absorbance at 1650 cm^{-1} has intensely decreased when it was exposed to UV light. While in Figure 2-2, it shows the change in the ratio of A_{1650}/A_{1440} after a different duration of UV irradiation. The ratio was decreased drastically at the beginning, but gradually decreasing down after 60 s. This is expected because when the cross-linking occurs, the amount of –CH=CH- decreases, but at the same time, the coatings become more rigid and the mobility of the polymer chains is reduced causing the reaction to slow down (Teck and Seng, 2011).

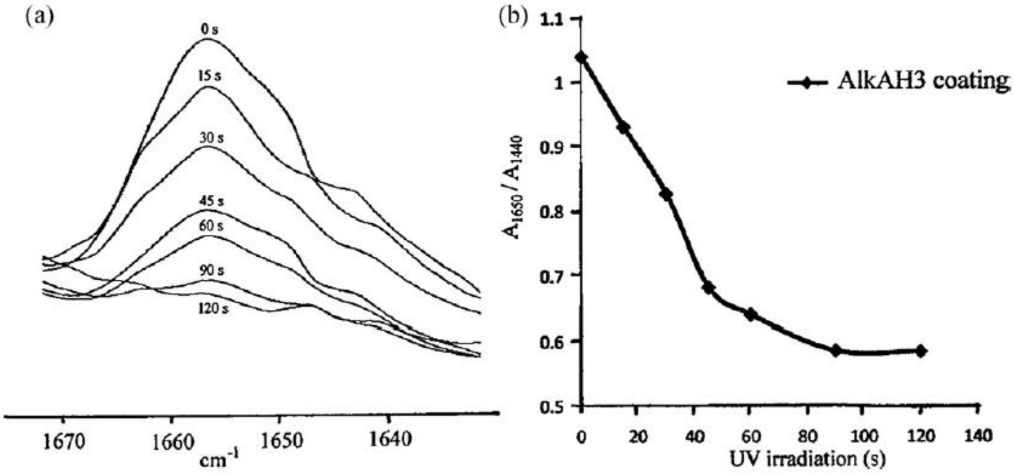


Figure 2-3: FTIR spectra of AlkAH3 and ration A1650/A1440 of AlkAH3

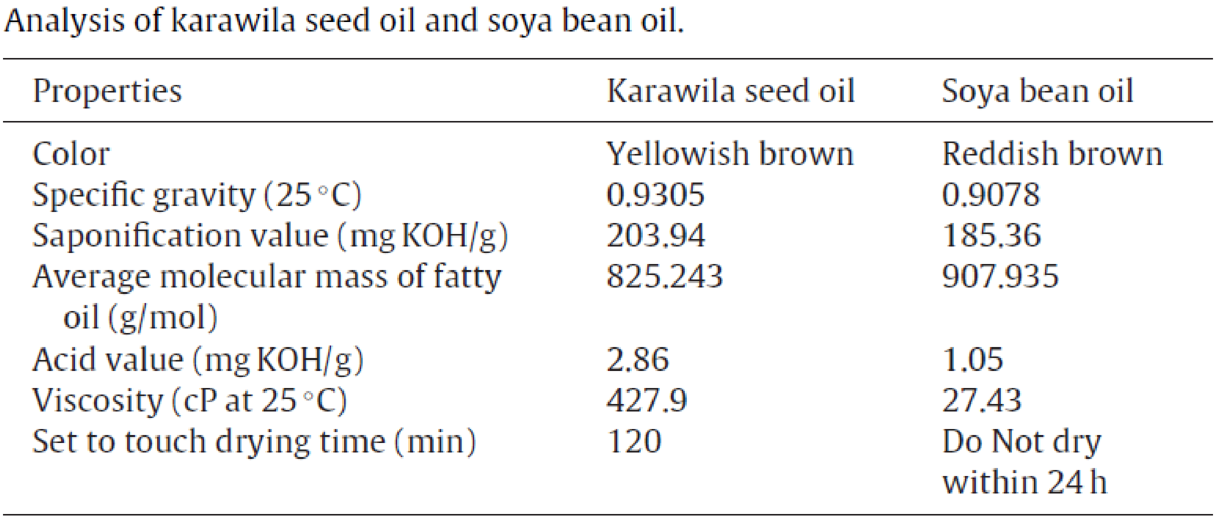
Based on Desmond Teck and Seng Neon Gang (2011) findings, they concluded that the drying palm stearin alkyd was converted into an environmentally friendly UV-curable resins by assimilating different amounts of Maleic anhydride into an alkyd resin and mixed with methyl methacrylate (MMA) as active diluents together with a low level of UV photo initiator that is benzophenone. The water resistance of the coating also has refined when the amount of un-saturation was increased. Other than that, the modified alkyd resins can produce a good coating with a good film characteristics. Teck et al. (2011) research's results discovered that the curing time is fast (less than 90s) which can accelerate the production process and economically save. The capability of faster curing time can minimize any possible emission of volatile organic compound (VOC). The performances of the maleated alkyd coatings were further enhanced by introducing a small amount of tri-functional monomer, trimethylolpropane triacrylate (TMPTA) as a cross linker into the UV curable resin formulation (Teck and Seng, 2011).

2.3.3 *Effect of karawila seed oil on synthesizing alkyd resins based on soya bean oil*

Soybean oil has been of the most popular vegetable oil in making alkyd resins because of its readily available and makes semi dying oil. De Silva, Amarasinghe, Premachandra and Prashantha (2011) has carried out their study to produce renewable alkyd resins based on soybean and karawila seed (*Momordica charantia*). The older binders called Tung oil (drying oil) is used for a very long time. But, because of its high reactivity compared to other drying oils, it is not widely used in alkyd synthesis. Karawila oil has the same properties as Tung oil and has a greater amount of unsaturated fatty acid and so, its a good drying oil (Prashantha et al, 2009).

A comparison of physiochemical properties of soya bean oil and karawila seed oil is shown in Table 1. The set to touch drying time of karawila seed oil was set at ambient conditions of 30°C and relative humidity of 50% and measured as 120 min which was quietly less than soya bean oil under the same conditions. The main reason for the fast drying of behaviour of karawila seed oil was because of the presence of high amount of octadecatrienoic acids (56%) (Prashantha et al, 2009).

Table 2-1: Analysis of karawila seed oil and soya bean oil



Analysis of karawila seed oil and soya bean oil.

Properties	Karawila seed oil	Soya bean oil
Color	Yellowish brown	Reddish brown
Specific gravity (25 °C)	0.9305	0.9078
Saponification value (mg KOH/g)	203.94	185.36
Average molecular mass of fatty oil (g/mol)	825.243	907.935
Acid value (mg KOH/g)	2.86	1.05
Viscosity (cP at 25 °C)	427.9	27.43
Set to touch drying time (min)	120	Do Not dry within 24 h

Based on the table above, higher acid value of karawila seed oil shows that it contains high amount of fatty acids compared to soya bean oil. While for the saponification value, karawila seed oil has significantly high number of esters compared to soya bean oil. The saponification value means the number of milligrams of KOH needed to saponify the esters and to neutralize the fatty acids in one gram of sample. So, the average molecular mass of fatty oil in Karawila seed oil is considerably less that the soya bean oil.

Meanwhile, for the specific gravity, the value of the specific gravity between these two oils are within the range of normal used vegetable oils (Dutta et al., 2004). As from the table above, even the molecular weight for karawila seed oil is less than soya bean oil, the viscosity and specific gravity are higher for karawila seed oil. Blayo et al. discussed that the visocisity of tung oil was significantly higher than linseed oil, whereas their molecular weights are comparable. They recommended that this behaviour can be explained by the presence of more polyconjugated sequences which can give rise to a higher cohesive enegy and later, an increased in viscosity. In the case of tung oil, the polar polyconjugated sequences in karawila seed oil may result in significantly higher viscosity and specific gravity than soya bean oil.

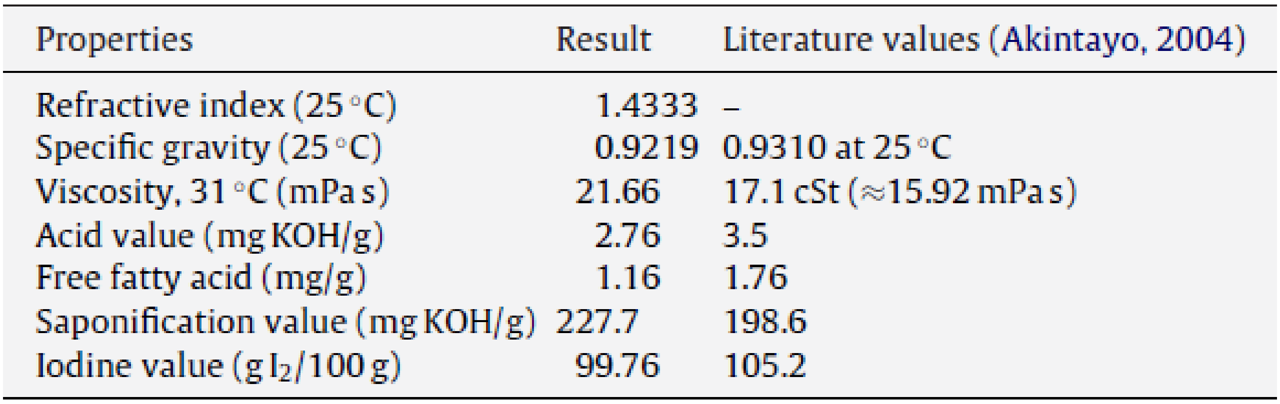
De Silva et al. (2011) found that karawila oil can replace tung oil as the drying oil because of its similar characteristics. Moreover, Karawila oil is having less molecular weight than soya bean oil but, the specific gravity and viscosity are higher for karawila oil. The extent of polymerization, drying behaviour and viscosity of alkyd resins were highly affected by the presence of karawila seed oil in the oil blend (De Silva et al., 2011). Despite that, the highest specific gravity and the lowest drying time were identified for the oil blend with 30% karawila seed oil and 70% soya bean oil (De Silva et al., 2011).

2.3.4 Jatropha curcas L. seed oil alkyd resins

Jatropha curcas L. oil (JCL) plant is also one of the alternative oil to produce a renewable alkyd resin. Usually, this plant is used to produce a good biodiesel fuel. Researched made by Odetoye, Ogunniyi and Olatunji (2010) tried to replace a common oil such as soybean oil with *Jatropha curcas*. The seed of this plant is not edible and poisonous because it contains a high toxic protein (Adolf et al., 1984). The seeds have a range of 30% to 45% of the oil. The oil has been analyzed to be mainly linoleoic and oleic fatty acids (Münch, 1986).

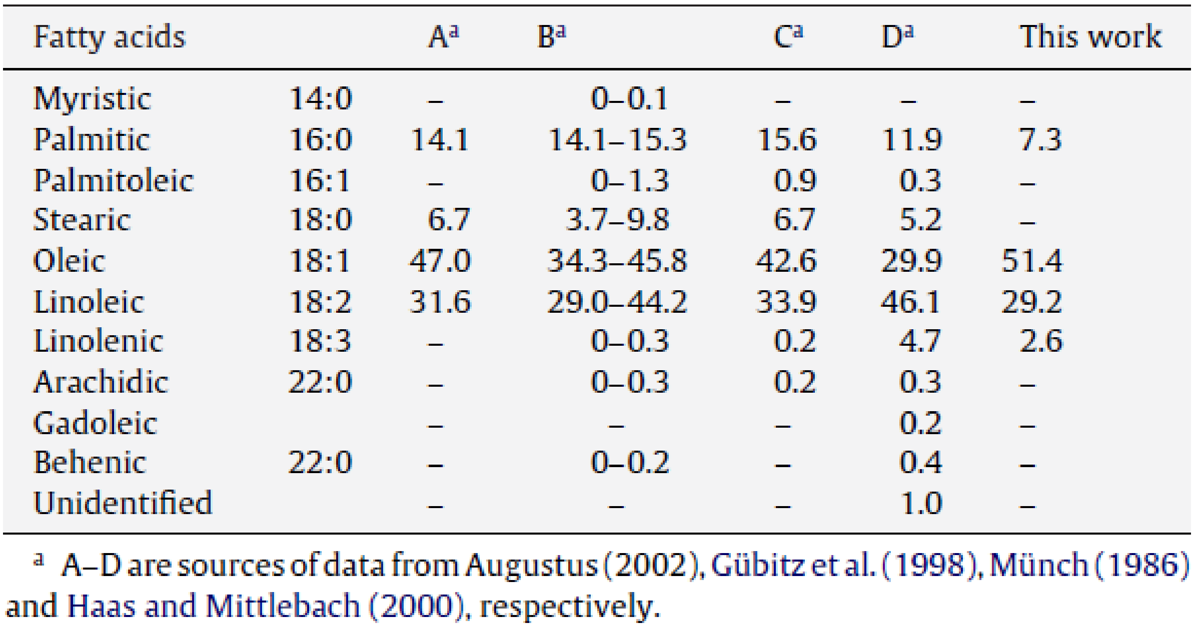
The solubility, viscosity, refractive index, specific gravity, acid value, free fatty acid, saponification and iodine value of JCL oil are tabulated in the table below.

Table 2-2: Properties of JCL seed oil



Properties	Result	Literature values (Akintayo, 2004)
Refractive index (25 °C)	1.4333	–
Specific gravity (25 °C)	0.9219	0.9310 at 25 °C
Viscosity, 31 °C (mPa s)	21.66	17.1 cSt (≈15.92 mPa s)
Acid value (mg KOH/g)	2.76	3.5
Free fatty acid (mg/g)	1.16	1.76
Saponification value (mg KOH/g)	227.7	198.6
Iodine value (g I_2/100 g)	99.76	105.2

Table 2-3: Fatty acid percentage composition of JCL oil



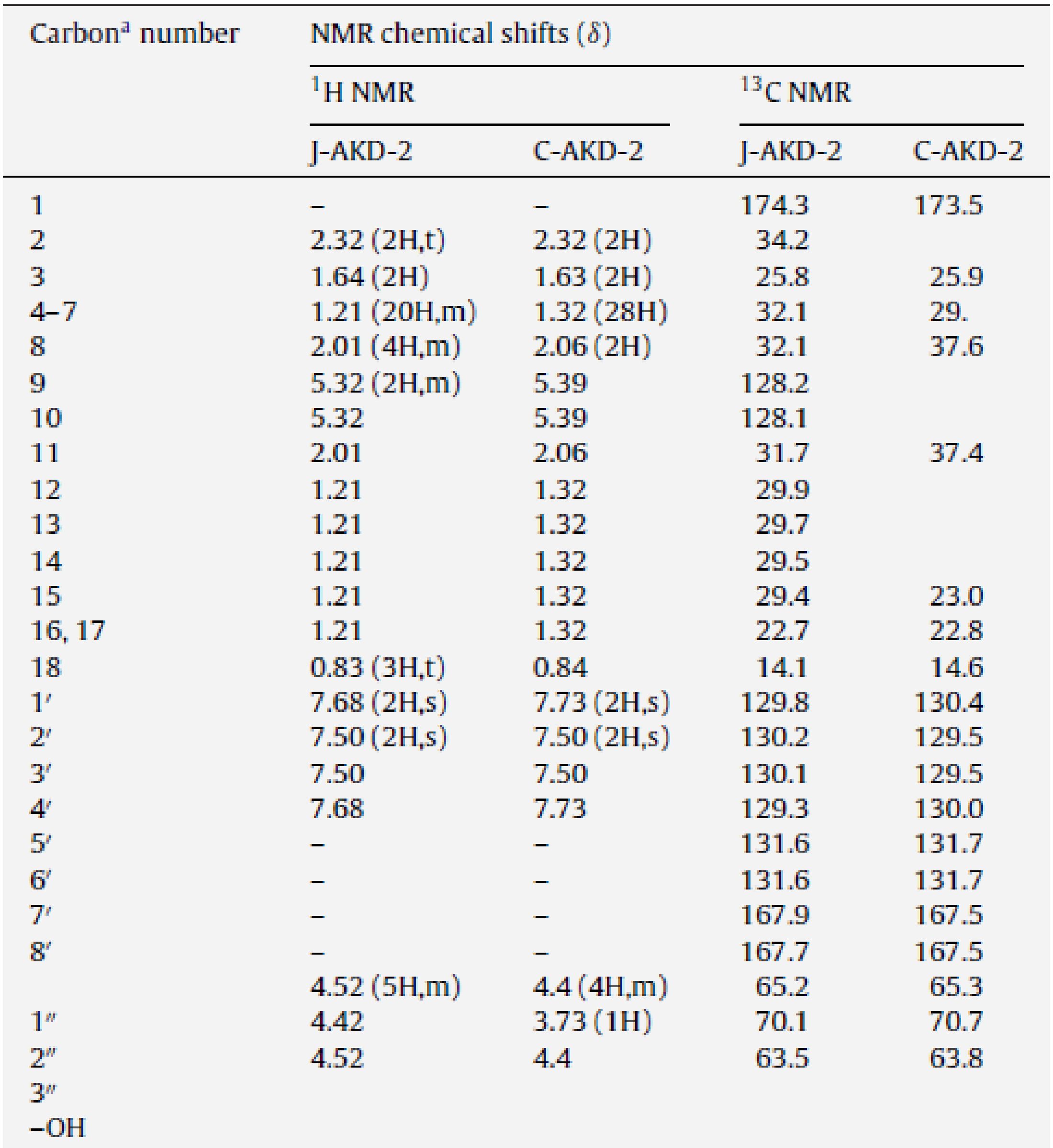
Fatty acids		A[a]	B[a]	C[a]	D[a]	This work
Myristic	14:0	–	0–0.1	–	–	–
Palmitic	16:0	14.1	14.1–15.3	15.6	11.9	7.3
Palmitoleic	16:1	–	0–1.3	0.9	0.3	–
Stearic	18:0	6.7	3.7–9.8	6.7	5.2	–
Oleic	18:1	47.0	34.3–45.8	42.6	29.9	51.4
Linoleic	18:2	31.6	29.0–44.2	33.9	46.1	29.2
Linolenic	18:3	–	0–0.3	0.2	4.7	2.6
Arachidic	22:0	–	0–0.3	0.2	0.3	–
Gadoleic		–	–	–	0.2	–
Behenic	22:0	–	0–0.2	–	0.4	–
Unidentified		–	–	–	1.0	–

[a] A–D are sources of data from Augustus (2002), Gübitz et al. (1998), Münch (1986) and Haas and Mittlebach (2000), respectively.

The differences in the values of the oil properties and the literature values are probably because of the geographical factor (soil type) on the seeds. Plus, Table 3 shows the fatty acid composition of JCL oils which consists mainly of linoleic and oleic acids compared to other research made by Augustus (2002), Gubitz et al. (1998), Munch (1986), Haas and Mittlebach (2000). The raw oil has a faint yellow color which affects the color of resulting alkyd. And this is important in consideration in paint formulation. But, visual observation showed that bleaching of the oil used in the preparation of alkyd direct to an improvement of the alkyd resins.

H NMR and C NMR's spectrum were obtained for JCL oil, 60% (medium oil) alkyd C-AKD-2 and J-AKD-2. The data are summarized in Table 4.

Table 2-4: Chemical shifts of alkyd sample



Carbon[a] number	NMR chemical shifts (δ)			
	^{1}H NMR		^{13}C NMR	
	J-AKD-2	C-AKD-2	J-AKD-2	C-AKD-2
1	–	–	174.3	173.5
2	2.32 (2H,t)	2.32 (2H)	34.2	
3	1.64 (2H)	1.63 (2H)	25.8	25.9
4–7	1.21 (20H,m)	1.32 (28H)	32.1	29.
8	2.01 (4H,m)	2.06 (2H)	32.1	37.6
9	5.32 (2H,m)	5.39	128.2	
10	5.32	5.39	128.1	
11	2.01	2.06	31.7	37.4
12	1.21	1.32	29.9	
13	1.21	1.32	29.7	
14	1.21	1.32	29.5	
15	1.21	1.32	29.4	23.0
16, 17	1.21	1.32	22.7	22.8
18	0.83 (3H,t)	0.84	14.1	14.6
1′	7.68 (2H,s)	7.73 (2H,s)	129.8	130.4
2′	7.50 (2H,s)	7.50 (2H,s)	130.2	129.5
3′	7.50	7.50	130.1	129.5
4′	7.68	7.73	129.3	130.0
5′	–	–	131.6	131.7
6′	–	–	131.6	131.7
7′	–	–	167.9	167.5
8′	–	–	167.7	167.5
	4.52 (5H,m)	4.4 (4H,m)	65.2	65.3
1″	4.42	3.73 (1H)	70.1	70.7
2″	4.52	4.4	63.5	63.8
3″				
–OH				

Unfortunately, *Jatropha curcas* is not competitive as soybean oil, it has a high percentage of monosaturated oleoic and polysaturated linoleoic that's indicate a semi-drying property and worth to be investigate the possibilities of another alternative source other than soybean and rapeseed oil in producing alkyd resin. Odetoye et al. (2010) concluded that *Jatropha Caracas* is one of the most potential raw oil in the coating industry and suitable for alkyd resins.

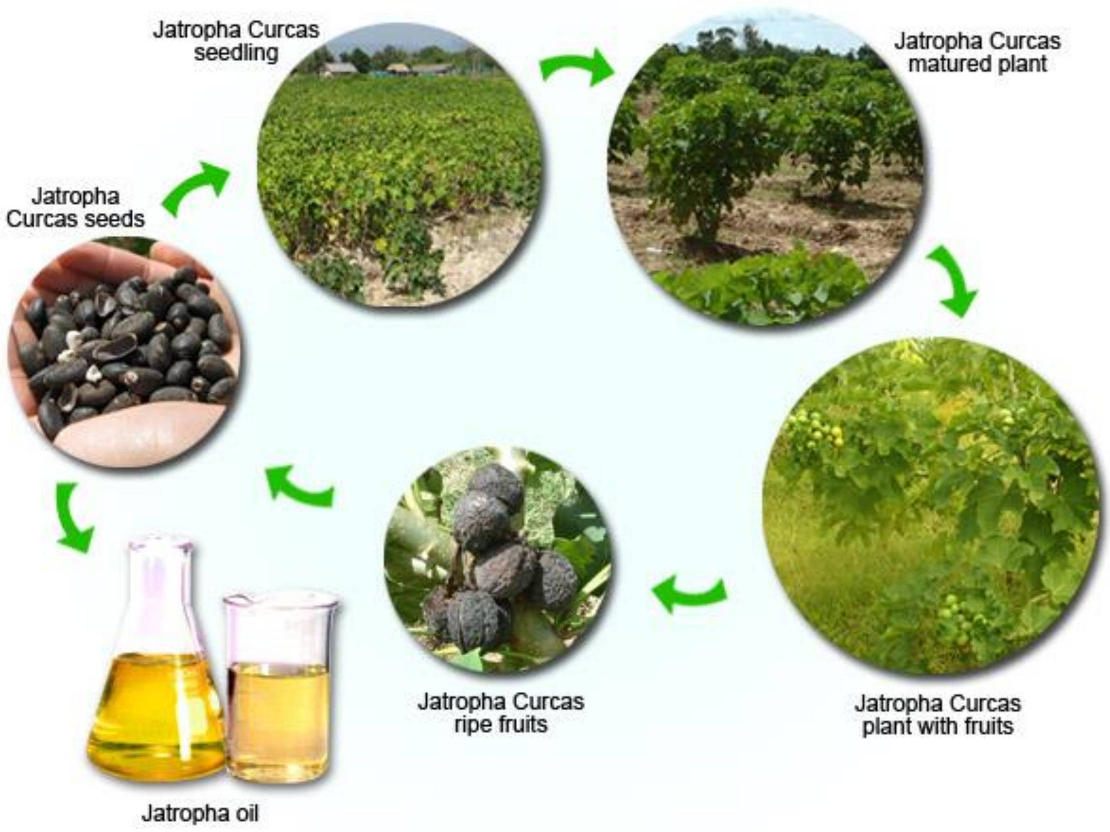


Figure 2-4: Jatropha Curcas life cycle

2.3.5 Bio-resin from banana sap

The sap from banana sap (BS) can be used as the raw materials for producing a bio resin. The banana plant (Musa Cavendish) is a monocotyledonous annual herbaceous plant and it has been suggested that it is suitable plant for bio-composite applications (Daneel, 2003). A survey has been conducted by Daneel et al. (2003) of the banana belt of the Limpopo province in South Africa. In his research, showed that the availability of sufficient quantities of a Musa cultivar that is suitable for processing composites. Once the banana fruit is collected, the plant is left to decompose and great amount of biomass remains because each plant that has borne fruit cannot be used for the next harvest. These pseudo stems become organic waste and can cause environmental pollution (Li, 2010). Furthermore, exploitation of waste, banana plants will be beneficial to the environment and also have profitable economic benefits (De Beer, 2008). The cellulosic fiber that obtained from the pseudo stem of the banana plant are widely used in tissue paper, clothing, paperboard etc. (Mohapatra, 2010). Banana fibers are used as and adsorbents to eliminate heavy metals (Low, 1995).

Polyester resins are commercially being prepared by a polycondensation reaction between saturated double and a mixture of unsaturated dibasic acid (John, 2008). The cross-linking may be accomplished by using polyols or an unsaturated di-carboxylic acid (Shaktawat, 2008) . Meanwhile in this literature, the banana sap was proposed to an esterification process using maleic anyhydride and propylene glycol. The removal of water from the sap was subsequently affected.

A hybrid resin was formed using a polyester resin since it was difficult to produce a natural resin with banana sap. While for the remaining organics in the banana, it was reacted with the polyester resin. Polyester resins are cost effective and there is a large market in South Africa. The locally available in South Africa banana sap is compatible with the polyester resin (Pau, Kanny, & Redhi, 2012).

The result was analysed using FTIR in this literature. As shown in Figure 2-5 , the carbonyl group of maleic anyhydride (MA) were depicted at 1855 cm^{-1} and 1776 cm^{-1}. The FTIR analysis of propylene glycol (PG) and banana sap (BS) were dominated by hydroxyl moieties at 3310 cm^{-1} and 3320 cm^{-1} respectively. Meanwhile, the banana sap's peak at 1628 cm^{-1} maybe contributed to the presence of ketones and at 1030 cm^{-1} maybe attributed to C-O stretching. As the acid and the hydroxyl groups combine to form ester and water is removed in the polycondensation, the polyester chain grows as seen in Figure 2-6, during the processing at 2h, 12h, 13h, and 13.5h. When the resin was processed and water is removed from BS, the O-H band at 3400 cm^{-1} was slowly disappeared. Futhermore, the carbonyl stretch at 1709 cm^{-1} and 1716 cm^{-1} steadily becoming more pronounced as the esters were formed. Lastly, the peak at 1640 cm^{-1} regularly disappeared as the –C=C- stretch breaks (Pau, Kanny, & Redhi, 2012).

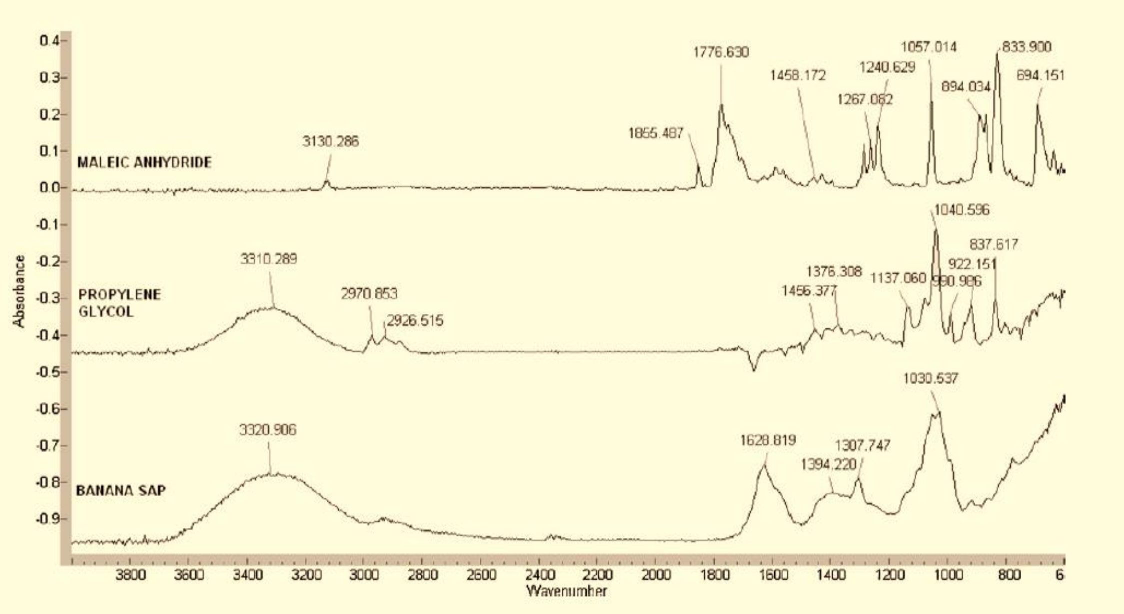


Figure 2-5: FTIR analysis on maleic anhydride, propylene glycol and banana sap resin

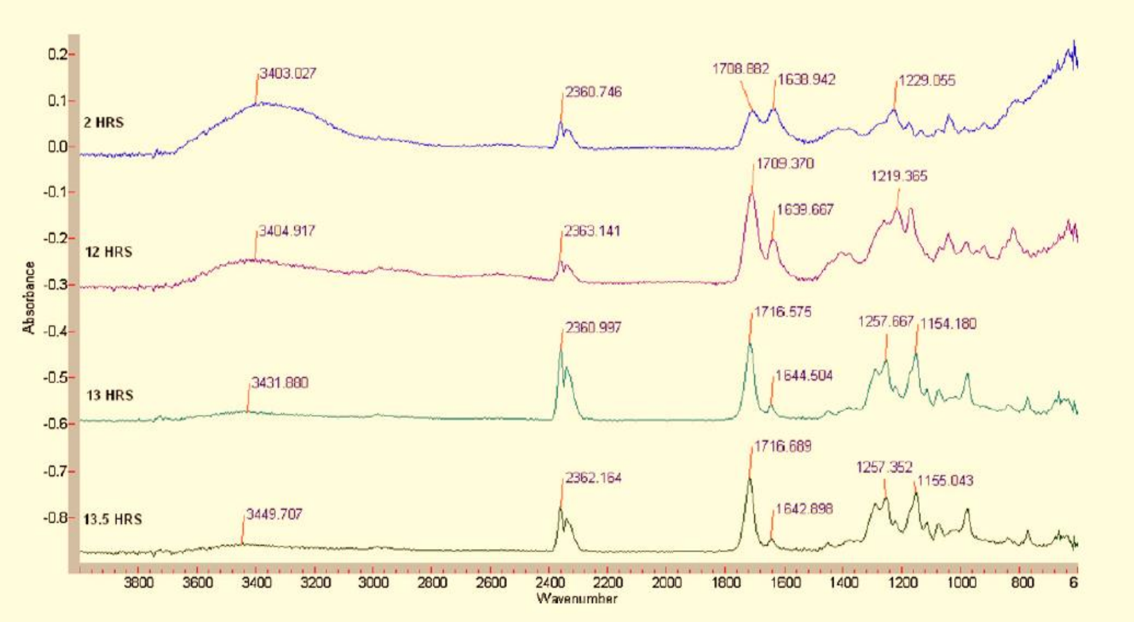


Figure 2-6: FTIR analysis of polyester chain based on time