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## ORIGINAL ARTICLES

# Exploring the effect of styrene and anhydride ratio on the coating properties of non-drying vegetable oil based alkyd resin

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### KEYWORDS

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 Palm kernel oil;  
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 Non-drying oil

**Abstract** The synthesis of oxy-polymerizable alkyd from non-drying palm kernel oil was studied. Three alkyd resins of medium oil length were prepared using phthalic anhydride, maleic anhydride, and glycerol at stipulated ratios. The prepared alkyd resins were copolymerized with styrene using benzoyl peroxide (BPO) as the free radical generator at 150 °C for 3 h. The styrenated alkyds and palm kernel oil-modified alkyds were all characterized for their physico-chemical properties following standard methods. The styrenated and unstyrenated alkyds were tested for drying schedule, solubility, adhesion, abrasion resistance and chemical resistance. All the resins showed good properties. The styrenated alkyds gave faster drying time, better adhesion, abrasion resistance, and chemical resistance. Unlike the unstyrenated alkyd which was only resistant to water, brine, and acidic media, the styrenated alkyds were also resistant to alkalis. Structural elucidation of the raw materials and their copolymers was done with Fourier Transform Infrared (FTIR) and GC–MS instrumental technique. It can be concluded that styrenated alkyds offer improved potential applications in surface coating purposes.

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## 1. Introduction

Alkyd resin or oil-modified polyester, traditionally, is the most extensively used synthetic resin in the surface-coating industry. Alkyd-based coating is well known for its fast dryness, good

corrosion protection, high gloss and ease of application even over poorly treated surface. The chemistry of the structural units connecting the ester groups allows alkyds to have immense diversity and versatility, such as labile biomedical matrices, liquid crystals, fibers and temperature resistant performance materials (Patton, 1962; Athawale and Chamankar, 1998; Kanai et al., 2007; Aigbodion et al., 2003). The demand for alkyd resin for use in the surface coating industry has been increased tremendously in recent times (Akinawo, 1989). Consequently, there is an increased demand for drying oils required for the production of alkyd resins. These drying oils, which are regarded as standards in surface

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coating industry are still very scarce and expensive. Moreover, their alkyds are prone to yellowing due to high unsaturation.

Preliminary investigations have revealed the potential sources that could meet the country's requirement of vegetable oil for alkyd production when properly developed (Adefarati, 1986; Nwankwo et al., 1986), and palm kernel oil is one of them. Palm kernel oil has become one of the major edible oils in the world. It is classified as non-drying oil because of its low iodine value; palm kernel oil alkyds are not capable of forming coherent film by air oxidation. The limited unsaturation in the fatty acid chains of this oil is responsible for its inferior curing properties compared to other drying oil based resins. Thus, curing agent and dryer are needed in the curing process. There is little or no report on the use of palm kernel oil alone in making alkyds for coating application.

Despite the advantages of palm kernel oil-modified alkyds such as good adhesion, film flexibility, color, gloss broader temperature range application, etc., there are some drawbacks, for instance, its susceptibility to alkali as a result of splitting of the ester linkages by hydrolysis; this reaction is very typical of esters. In addition, compared to other synthetic resins, palm kernel oil-modified alkyd resin is relatively slow in drying. However, it has been demonstrated that non-drying oil can be modified by several physical (blending) and chemical (copolymerization) processes to give products that could meet up with a wide range of applications. Pressure-sensitive adhesives using palm kernel oil-based alkyd resins as a tackifier, have been synthesized by step-wise polymerization (Lee and Gan, 2013). Non-drying palm oil was mixed with tung oil to produce a workable coating resin (Saravari et al., 2005). In another account, mixing palm oil based-alkyds with melamine gave baking enamels (Gan and Kim, 1999).

The present study, therefore, seeks to investigate the effect of styrene modification on the properties of palm kernel oil alkyd resin as it is known that polystyrene is very resistant to the action of alkali both in alcoholic and non-aqueous media. The study was enhanced by varying the ratios of phthalic and maleic anhydride.

## 2. Experimental

### 2.1. Materials

Laboratory-grade phthalic anhydride with assay 99.7%, maleic anhydride with assay 99.0%, glycerol with assay 99.7%, styrene with assay 99.5%, xylene with assay 98%, benzoyl peroxide with assay 96%, and manganese (drier) from British Drug House (Poole, UK) were used in the preparation of alkyds and styrenated alkyds. The palm kernel oil (PKO) was purchased from Head Bridge Market, Onitsha, Anambra State.

### 2.2. Methods

#### 2.2.1. Refining of the crude PKO

50 ml of crude PKO was measured and poured into a beaker; the same quantity of water was added into the beaker. The mixture is heated for about 25 min in an electric heater after which it is allowed to cool, settle and later decanted. The upper phase discharge is the washed oil with lesser impurities while the lower phase discharge is the water containing impurities.

The washed oil is treated with phosphoric acid of the same quantity. A reaction time of 20 min is allowed during which the gums (phosphatides) are precipitated. The acid treated oil is then continuously dosed with caustic soda. The concentration and amount of the alkali used varied with the free fatty acid (FFA) content of the oil. Intimate contact between the alkali and the oil is ensured by the choice of a well-designed mixer. The alkali results in the FFA forming precipitated soaps which were removed through centrifuge. The neutralized oil was then washed. The oil is washed with water to remove the soap impurities present. The oil-water mixture passes through a centrifuge separator where the heavy phase discharge contains soapy water and the light phase discharge is water-washed oil with a soap content of less than 80 ppm which is subsequently reduced at the next bleaching stage.

#### 2.2.2. Dehydration of palm kernel oil

50 cm<sup>3</sup> of the refined PKO was poured into a conical flask and mixed with 0.5 g H<sub>2</sub>SO<sub>4</sub> as a catalyst. The mixture was then heated to 250 °C and the temperature maintained for an hour in an inert atmosphere of nitrogen. At the end of this period, the source of heat was removed and the dehydrated oil was allowed to cool.

#### 2.2.3. Physico-chemical analysis of the crude and refined palm kernel oil

The physico-chemical properties of dehydrated oil such as acid value, iodine value, saponification value, and specific gravity were determined using American Oil Chemists Society methods (AOCS) (Nwankwo et al., 1986) and viscosity was measured following a standard procedure using Oswald viscometer. The fatty acid composition of palm kernel oil was determined using gas chromatography (GC).

#### 2.2.4. Synthesis of PKO fatty acid based-alkyd

Three different alkyds were prepared with dehydrated palm kernel oil, glycerol, phthalic anhydride, maleic anhydride using lithium hydroxide as catalyst according to the formulations shown in Table 1. The reactions were carried out in a three necked round bottom flask titled with a motorized stirrer, a dean-stark trap titled with water-cooled condenser and nitrogen in let tube at a temperature of 220–260 °C. Xylene was employed as an azeotropic solvent. During alcoholysis, the triglycerides of PKO were converted to monoglycerides by reacting with glycerol, catalyzed by lithium hydroxide at 180–200 °C. Phthalic anhydride, glycerol and xylene were then added, and polymerization was carried out at 220–250 °C for more than 6 h. The required maleic anhydride was then added to complete the reaction. The concentrations of alkyd solutions were determined and finally diluted to 70–75% by the

**Table 1** Recipe of the preparation PKO fatty acid based-alkyd.

Resin type	Oil length (%)	Glycerol (g)	PbO (g)	PA (g)	MA (g)
Resin-A	50	50	1	50	
Resin-B	50	50	1	25	25
Resin-C	50	50	1	15	35

addition of xylene. The progress of reaction was followed by measuring the evolved water of reaction and periodically checking the acid number by titration in accordance to ASTM D1980-87 (1998) with some modifications.

#### 2.2.5. The copolymer synthesis

The styrenated alkyds were prepared by post copolymerization of the alkyd resin, heated in the presence of an initiator, benzoyl peroxide, under reflux at 120 °C for 3 h. Post-copolymerization using a known weight of alkyd dissolved in toluene with the specified amount of styrene (Fig. 1). The system was purged with nitrogen for 5 min. The alkyds were with-drawn into 100 ml flask and were heated to 90 °C and stirred at 250 rpm. The pre-weighed benzoyl peroxide (BPO) dissolved in the small amount of toluene was introduced into the reactor and the temperature was maintained at 95–120 °C for 6 h under reflux. The copolymers were prepared using styrene and alkyd in three different ratios.

#### 2.2.6. Evaluation of coating properties of the alkyds and its copolymers

**2.2.6.1. Drying time test.** The prepared alkyd resin and styrenated resin mixed with drier were thinned with xylene and applied as thin panels. The samples were checked frequently to trace the dryness or tackiness by using the finger tips.

**2.2.6.2. Chemical resistance test.** The cured films of resins and styrenated resins were immersed in various chemicals of different concentrations; tetraoxosulfate (VI) acid (0.1 M H<sub>2</sub>SO<sub>4</sub>), sodium hydroxide (0.1 M NaOH), sodium chloride (5% solution) and distilled water for 24 h at room temperature. After the time period, the weight loss was measured. An expression of the measurements such as excellent (not affected) fair (not affected but change in color) and poor (less affected) were used to indicate the chemical resistivity of the film with respect to their weight losses.

#### 2.2.7. Analysis of PKO, resins and styrenated resins

The analysis of the PKO was performed with a Thermo Finnigan Trace GC/Trace DSQ/A1300, (E.I Quadropole) equipped with a SGE-BPX5 MS fused silica capillary column (film thickness 0.25 μm) for GC–MS detection, and an electron

ionization system with ionization energy of 700 eV was used. Carrier gas was helium at a flow rate of 10 mL/min. Injector and MS transfer line temperatures were set at 220 °C and 290 °C respectively. The oven temperature was programmed from 50 °C to 150 °C at 3 °C/min, then held isothermal for 100 min, and raised to 250 °C at 10 °C/min. Diluted samples (1/100, v/v, in methylene chloride) of 1.00 μL were injected manually in the slitless mode. The identification of individual components was based on the comparison of their relative retention times with those of authentic samples on SGE-BPX5 capillary column, and by matching their mass spectral of peaks with those obtained from authentic samples and/or the Wiley 7N and TRLIB libraries spectra and published data. The structural and functional group of PKO, PKO based-alkyd resins and styrenated alkyd resins were analyzed by Buck M530 Fourier Transform of Infrared Spectrophotometer (FTIR). The FT-IR equipment was operated with a wavelength range of 4000–500 cm<sup>-1</sup>.

#### 2.2.8. Adhesion test

This test was performed to measure the strength of the bonds formed between the coating material and the applied surface. The dried films were cut by cross hatch and the coatings were cleaned using a brush. A scotch tape was adhered on the film and peeled off quickly at 180° angle. The peeled off grid area on the tape were observed by a magnifier.

#### 2.2.9. Abrasion resistance test

This test was performed to measure the resistance of coating films against abrasion caused by an abrasive falling from a specified height through a guide tube onto a coated metal. Silica sand was used as the abrasive agent. It was onto the coated metal until some scratching was detected. The volume of sand which changes the thickness of the film by certain extent determines the abrasion resistance. The abrasion is given in terms of amount to sand required to remove 1 μm thickness from coating material.

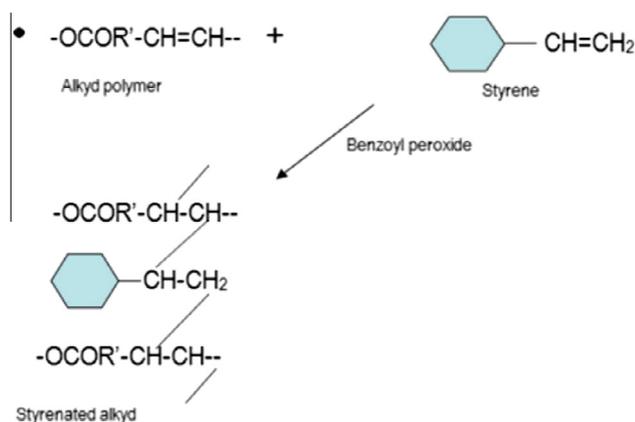
#### 2.2.10. Solubility test

The solubility of the palm kernel oil modified resin and styrenated alkyd resin was tested in different solvents such as xylene, benzene, toluene, acetone, ethanol and methanol. 2 g of each resins and styrenated resin were dissolved in 50 cm<sup>3</sup> of each of the solvent and the effects were observed and recorded.

### 3. Results and discussion

#### 3.1. Characterization of the PKO

The results of refined palm kernel oil characterization are presented in Table 2. The characterization was done in order to know whether the oil will be used for the preparation of alkyd resins. The acid value was in a close agreement with the literature value. The iodine value showed that the oil is not in the category of drying oils or semi-drying oils. The iodine value of palm kernel oil showed that the oil is saturated and as such could not be used for the production of alkyd resin without modification. Also, the saponification value obtained shows that the oil contains a high molecular weight of fatty acid.



**Figure 1** Schematic depiction of the mechanism of styrenation.

**Table 2** Characterization result of refined PKO.

Parameters	Value	Literature
Color	Yellow	
Specific gravity (25 °C)	0.919	
Viscosity (poise)	0.388	
Acid value (MgKOH/g oil)	18.123	15.280
Saponification value (MgKOH/g fat)	181.144	143.16
Iodine value (gI <sub>2</sub> /100 g oil)	45.067	44.015
FFA	4.0615	1.1007

**Table 3** Fatty acid profile of PKO.

Components	Name	Concentrations (ppm)	% Concentration
C20	Behenic acid	0.0266	0.3234
C17	Margaric acid	2.3030	28.007
C18:2	Stearic	2.8916	35.163
C14	Myristic acid	0.6756	8.216
C16	Palmitic acid	1.0166	12.363
C16:2	Palmitoleate	0.4804	5.842
C18	Methylstearate	0.0055	0.0668
C12	Lauric acid	0.5841	7.1034
Total		8.228	

Saponification value is used to assess the mean molecular weight of the fatty acids of low or fairly low molecular weight and a value below 190 indicates the presence of a high molecular weight of fatty acids. This implies that saponification value is inversely proportional to the molecular weight of the fatty acids present in oil (Minife, 1970). The determined free fatty acid (FFA) is quite different from the literature value. This variation could have arisen from poor storage. It is known that oil contains the enzyme lipase, which under suitable conditions (moisture and temperature) hydrolyzes the triglycerides (oils) into free fatty acids. Therefore, good storage of oil is very important to prevent the oil from deterioration and minimize the production of free fatty acids in oil seeds. Free fatty acids have been reported (Mraz et al., 1957), to inhibit the speed of the alcoholysis reaction in the synthesis of alkyd resin. Therefore, deteriorated oil is unsuitable for the production of alkyd resins.

### 3.2. Fatty acid compositions of PKO

The fatty acid composition of PKO is presented in Table 3. The fatty acid profile reveals that the oil is predominated by stearic acid (35%); the constituents of high values were margaric acid (28%) and palmitic acid (12.363%). This showed that the oil is highly saturated and could be used for manufacturing soap, washing powder, and other personal care products. Its saturation also shows that if it is used in the production of alkyd resin, it will produce alkyd of slower drying rate but color retentive. Palm kernel oil, therefore, if structurally modified, may give alkyd resin with better performance characteristics.

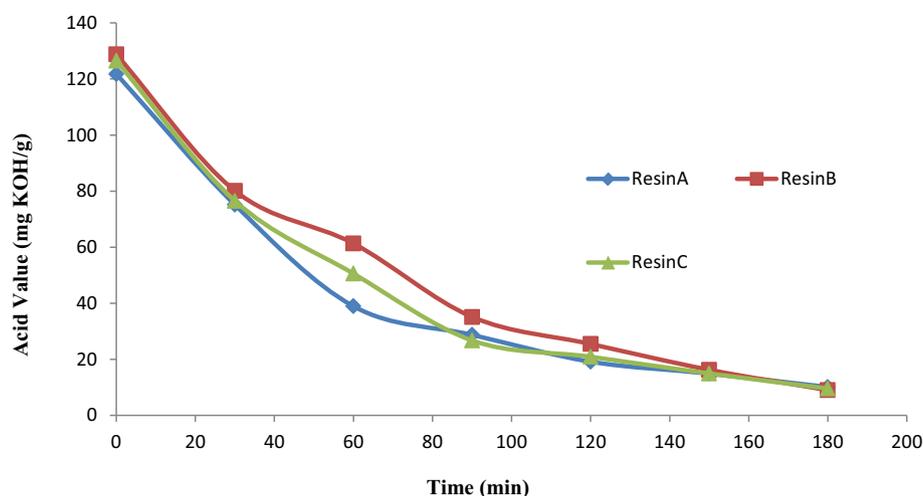
### 3.3. Alkyd resin studies

When glycerol was used as the polyol in an alcoholysis reaction, the product contained  $\alpha$  – monoglyceride,  $\beta$  – mono-

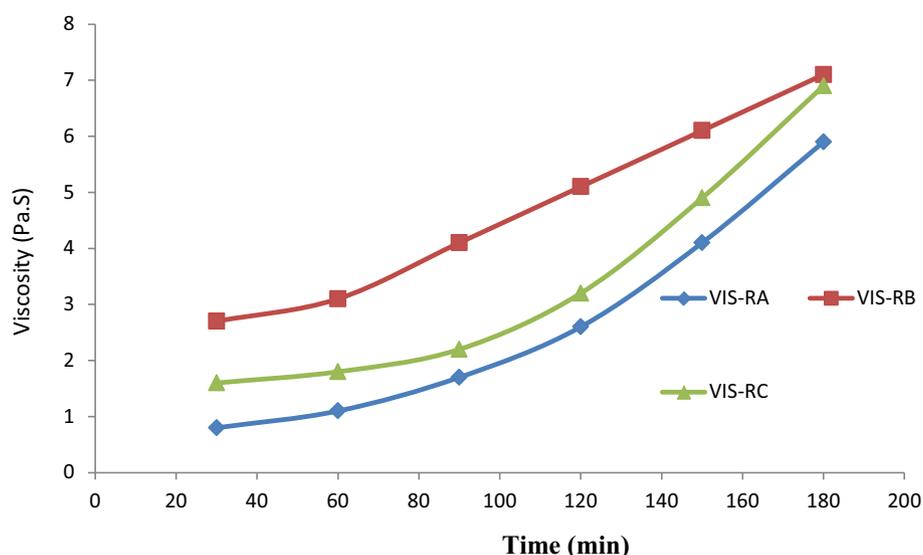
glyceride,  $\alpha^1$  – diglyceride,  $\beta^1$  – diglyceride, triglyceride or oil and glycerol (Aigbodian, 1991). Alcoholysis mixture with a high  $\alpha$  – monoglyceride content produces alkyds with better drying properties. In an alcoholysis reaction, the rate is synonymous to the time taken by the alcoholysis mixture to give a positive methanol tolerance test. The alcoholysis rate is inversely proportional to time. The shorter the time of reaction, the higher the alcoholysis rate and vice versa. The second stage is polyesterification which is a condensation polymerization reaction. In polyesterification reaction, the rate constant of polycondensation reaction is independent of the molecular size, the rate of reaction is usually measured by determining the concentration of the functional groups as a function of time (O dian, 1970). The process of the reaction was monitored by the titration of unreacted carboxylic acid groups when samples were removed from reaction mixture at 30 min intervals. From Figs. 2 and 3 it was observed that the initial acid value of the reaction mixture decreased with the increasing time and its viscosity increases with the increasing time. Fig. 2 shows initial sharp decreases which later slowed down. The abrupt drop in the acid value was attributed to the difference in reactivity's of primary –OH and secondary –OH groups of the glycerol with carboxyl group of the phthalic and maleic anhydride. Faster reaction during early stages of the reaction may be attributed to the high conversion rate of glycerol and phthalic/maleic anhydride. It has been reported that  $\alpha$  – OH group of glycerol reacts faster than  $\beta$  – OH group. That might be what caused the initial rapid decrease in acid value which corresponds to the time when  $\alpha$  – OH groups reacted with phthalic and maleic anhydride. But in the later time, the gradual decrease of the acid value was as a result of reaction of  $\beta$  – OH with phthalic and maleic anhydride (Aigbodian and Pillai, 2001). The increase in the viscosity as the reaction progressed was as a result of the reaction of  $\alpha$  – OH and  $\beta$  – OH groups of glycerol. But the deviation in linearity indicates the portion at which the secondary hydroxyl ( $\beta$  – OH) group (which is less reactive than  $\alpha$  – OH) reacts with the phthalic and maleic acid to form three dimensional molecules (Yahaya et al., 2001). The region of deviation from linearity has been termed nucleation phase (i.e. the beginning of microgel formation) (Yahaya et al., 2001). Based on the type of acid anhydride used in the preparation, the resin B (50% MA and 50% PA) and (75% PA and 25% MA) had the highest viscosity. This is because of the existence of a double bond in the maleic anhydride component which subsequently leads to a high cross linking (Murillo and Lopez, 2014).

### 3.4. Styrenated alkyd resin studies

Copolymerization of styrene with palm kernel oil-modified alkyd resin yields a transparent product with better impact strength, increased solvent resistance and higher softening point. In the study of polystyrenation process, the acid value does not change significantly as the reaction progresses. This shows that thermal polymerization did not occur under the reaction prevailing conditions. Only iodine and viscosity values change significantly as the reactions progress as shown in Figs. 4 and 5. There was an initial increase in the iodine values as the level of substitution increased instead of decreasing. This may be due to the double bonds in the styrene structure. But as



**Figure 2** Variation of acid value with time.



**Figure 3** Viscosity variation with time of alkyds resins, A, B and C.

the reaction proceeds after 1hr; it was observed that the iodine value decreased. This could be due to the consumption of the double bond as polymerization progressed (Ikhuoria, 2011). It is an expected result because double bonds are consumed during the reaction. The increase in viscosity (as shown in Fig. 4) throughout the reaction indicates the high level of cross linking.

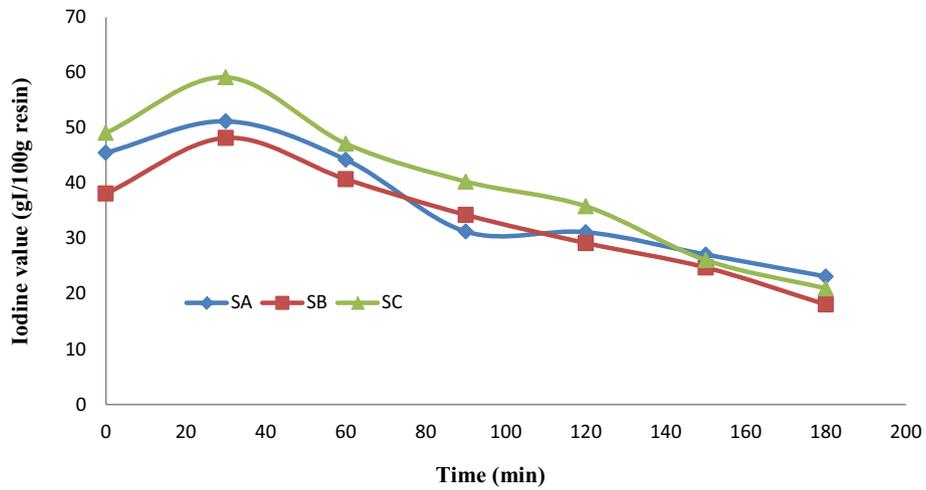
### 3.5. Variation of degree of copolymerization with time

The variation of the degree of copolymerization (DC) with time is shown in Fig. 6. These plots show a linear behavior up to a certain point followed by a deviation from linearity. The reason for this trend was attributed to the point of styrene substitution leading to the formation of linear and three dimensional molecules respectively (Ikhuoria, 2011). It was also seen from these plots that after 2 h, there was an indication of linearity again. This linearity confirmed the continuous

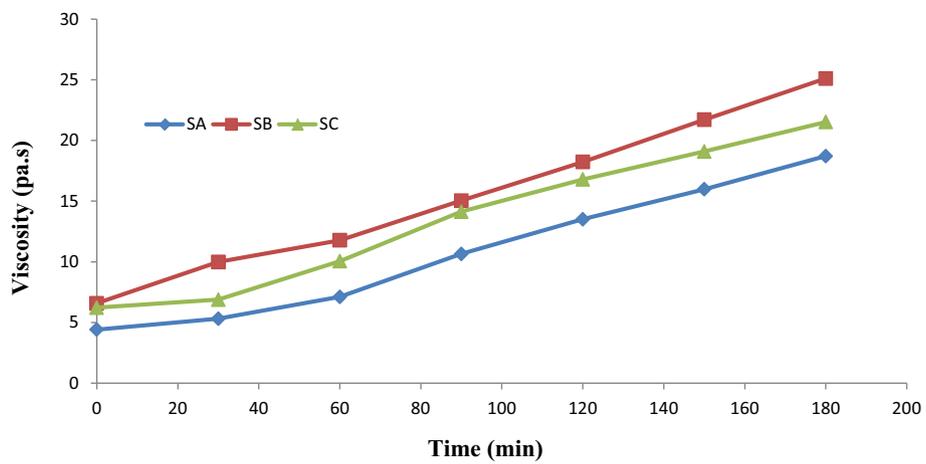
consumption of double bonds in styrene structure leading to a second order kinetic and at this period, its conversion increases. The plots showed that the styrenated alkyd resin with 50% MA and 50% PA has the highest degree of copolymerization. The reason could be high cross linking of maleic anhydride in the base alkyd resin.

### 3.6. Physicochemical properties of alkyd resins and styrenated alkyd resins

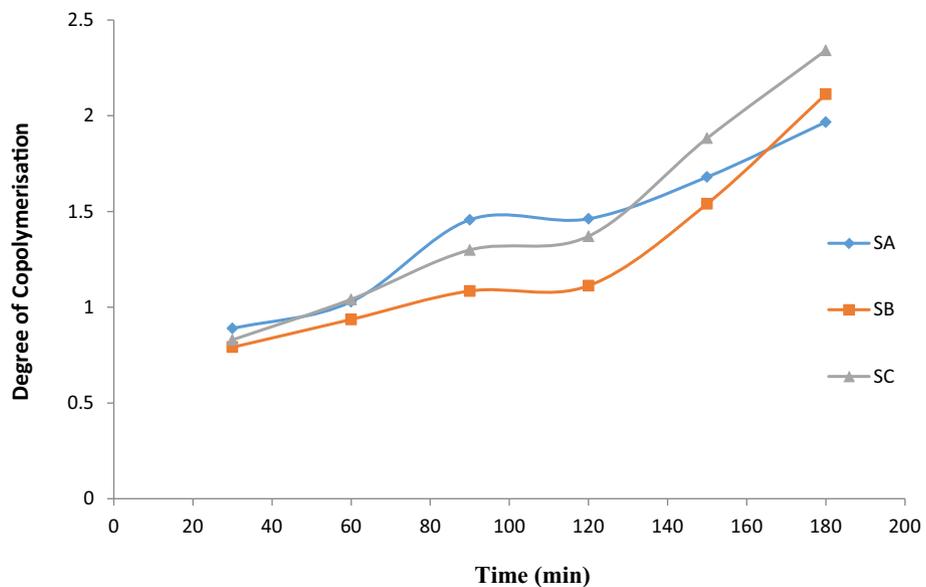
The physico-chemical properties of alkyd resins and styrenated alkyd resins are shown in Table 4. Their properties are quite comparable except their iodine values and viscosities. The decrease in the iodine values of styrenated alkyd resins was due to the consumption of the double bonds as polymerization progressed. The increase in the viscosity of styrenated resins could be as a result of high cross linking due to the presence of double bonds in the styrene structure.



**Figure 4** Iodine vs time for styrenated resins A, B and C.



**Figure 5** Viscosity vs time for styrenated resins A, B, and C.



**Figure 6** Variation of degree of copolymerization with time.

**Table 4** Alkyd and styrenated alkyd resin characterization.

Property	Alkyd resins			Styrenated alkyd resins		
	A	B	C	SA	SB	SC
Color	LB	LB	LB	LB	LB	LB
AV (MgKOH)	10.098	8.976	9.537	10.659	12.342	12.18
IV (gI <sub>2</sub> /100 g)	43.15	36.80	45.37	23.13	20.80	25.18
SG(30 °C)	0.925	0.931	0.933	0.992	0.985	0.978
Viscosity (pa s)	4.47	6.48	5.42	18.71	25.11	21.52

AV = Acid value; SG = Specific gravity; IV = Iodine value, LB = Light brown.

### 3.7. Performance characteristics of PKO alkyds and styrenated alkyds

The performance characteristics of the alkyd resins and styrenated alkyd resin in terms of drying schedule and chemical resistance are shown in Table 5. The alkyd resins A, B and C were set-to-touch at 50, 30 and 38 min; surface dried at 5, 3½ and 4 h and were completely dried at 12, 11 and 11½ h later. Their chemical resistance showed that they are resistant to acid, brine and water but susceptible to alkali, as they were removed in alkali medium. This poor resistance to alkali occurs because ester groups of resins are readily attacked by alkalis and hydrolyzed by acid (Ikhuoria, 2011). The drying schedule of the styrenated alkyd resins as shown in the same table depicts an improvement from that of the pure alkyd resins, surface dry in 2¼, 1¼ and 1¾; and dry through at 5½, 3 and 4 h. The chemical resistance of the styrenated alkyds is similar and also shows an improvement on the pure alkyd resins. Unlike the unstyrenated alkyd which was only resistant to brine, water and acid, the styrenated alkyd resins also showed resistance to alkali. This means that styrenation assisted in making the ester linkages of the polyester from alkali hydrolysis.

### 3.8. Infrared spectral analysis of the PKO, its alkyds and styrenated alkyd samples

Infrared spectral analysis of refined PKO is shown in Fig. 7. One remarkable feature of the spectra is the presence of unsaturation in the oil as is evident by the bands at 1515.964 cm<sup>-1</sup> and 2783.766 cm<sup>-1</sup>. These bands reveal the presence of alkene and alkyne compounds stretched at CH and C=C. The broad peak in the range of 817.0349–887.7197 cm<sup>-1</sup> corresponds to chloro compounds. The peak at 1837.158 cm<sup>-1</sup> indicates cyclic ester group (RCOOR) stretching at CO. The band at

2135.62 cm<sup>-1</sup> is due to carboxylic acid (RCOOH) group stretching at CO. The thiocyanate (R–S–C≡N) and nitrile (R–C≡N) groups are indicated at 1990.38 cm<sup>-1</sup> and 2378.568 cm<sup>-1</sup> peaks. Also at peaks of 1321.513 cm<sup>-1</sup> and 1397.105 cm<sup>-1</sup> methyl (CH<sub>3</sub>) group was indicated. The peaks at 1636.559, 1687.543, 2627.454 and 3734.674 cm<sup>-1</sup> indicate the presence of amine groups. Finally, the peak in the range 3043.559–3602.68 cm<sup>-1</sup> indicates the presence of alcohol (RCHOH) group (OH) stretching. The IR spectral of alkyd resins and styrenated alkyd resins were shown in Figs. 8 and 9. The broad peaks in the range of 718.8449–888.433 cm<sup>-1</sup> correspond to fluoro and chloro compounds in both alkyd resins and styrenated resin. The presence of unsaturated compounds is evident by the bands at 1333.539 cm<sup>-1</sup>, 1590.997 cm<sup>-1</sup>, 1729.477 cm<sup>-1</sup>, 1889.156 cm<sup>-1</sup>, 1374.269 cm<sup>-1</sup>, 1856.35 cm<sup>-1</sup> and 2645.795 cm<sup>-1</sup>. These bands reveal the presence of alkene and alkyne compounds stretched at CH and C≡C in both alkyds and styrenated alkyds. This presence of unsaturated compounds in both resins and styrenated resins is an evidence that both alkyds and styrenated alkyds can dry at any particular time. The absorption band in the region of 2261.675 cm<sup>-1</sup>, 2234.842 cm<sup>-1</sup>, 2164.434 cm<sup>-1</sup> and 2378.737 cm<sup>-1</sup>, which corresponds to carbonyl group, is of particular interest. From the FT-IR spectrum, this region shows typical absorption of carbonyl group, which is sharp and strong in alkyd resins. However, for the styrenated alkyd resin, the peak is not broad and sharp; but rather, it is almost withdrawn or shortened. This could explain the reason why the styrenated alkyds are not removed in alkali medium, because the polystyrene moiety tend to shield the carbonyl group from hydrolysis of the strongly nucleophilic base, as it is known that the hydroxides attacks the carbonyl carbon to effect cleavage of the bond between the oxygen and the acryl group (Morrison and Boyd, 1992).

### 3.9. Adhesion

The adhesion of the resins and styrenated resins on both glass and metal substrates were found to be 3B and 5B for resins and styrenated resins respectively. No flaking or ribboning occurred after making cuts and applying the adhesives tape. The double bonds in the styrene structure of the styrenated resins improved the adhesion to the substrates.

### 3.10. Abrasion resistance

Abrasion resistance test results are given in terms of amount of sand required to remove 1 nm thickness from coating material.

**Table 5** Performance characteristics of PKO alkyd and styrenated alkyd samples.

Sample	Drying schedule			Chemical resistance			
	STT (min)	SD (h)	DT (h)	0.1 M H <sub>2</sub> SO <sub>4</sub>	0.1 M NaOH	5% NaCL	Distilled H <sub>2</sub> O
Resin-A	50	5	12	3	2	3	5
Resin-B	30	3½	11	3	1	3	5
Resin-C	38	4	11½	3	1	3	5
SA	25	2¼	5½	4	4	4	4
SB	15	1¼	3	5	5	4	3
SC	18	1¾	4	5	5	4	3

(1–5) = rate of chemical resistance, STT = set-to-touch, SD = surface dry, DT = dry through.

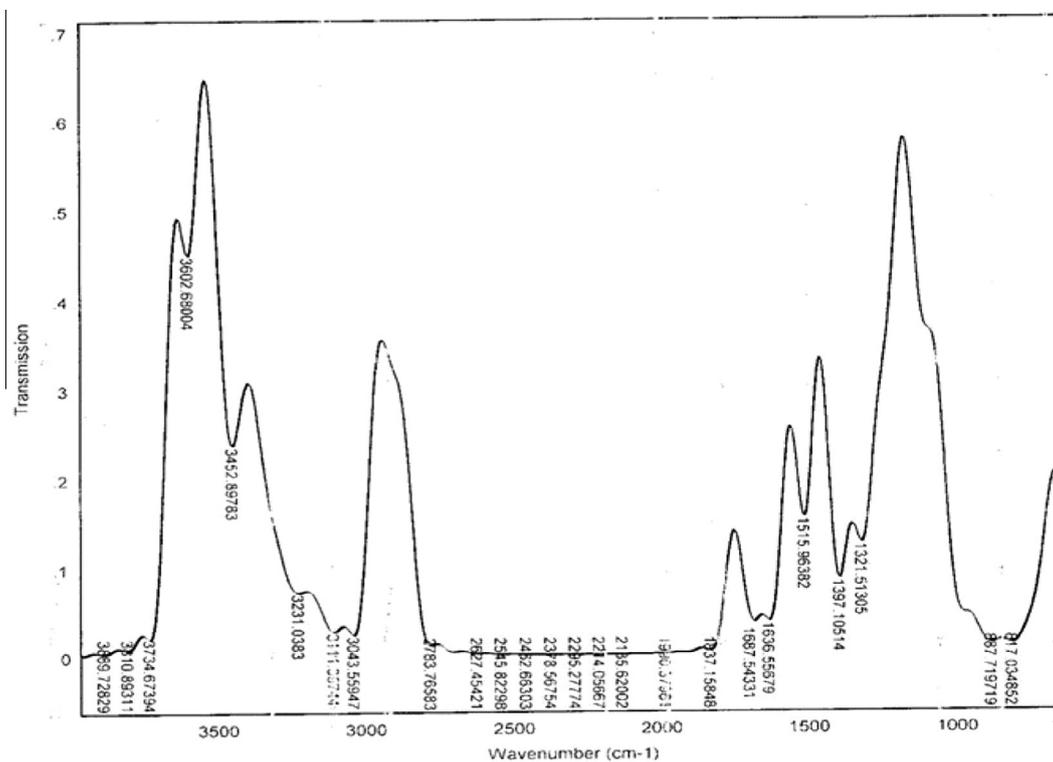


Figure 7 FTIR spectra of refined palm kernel oil.

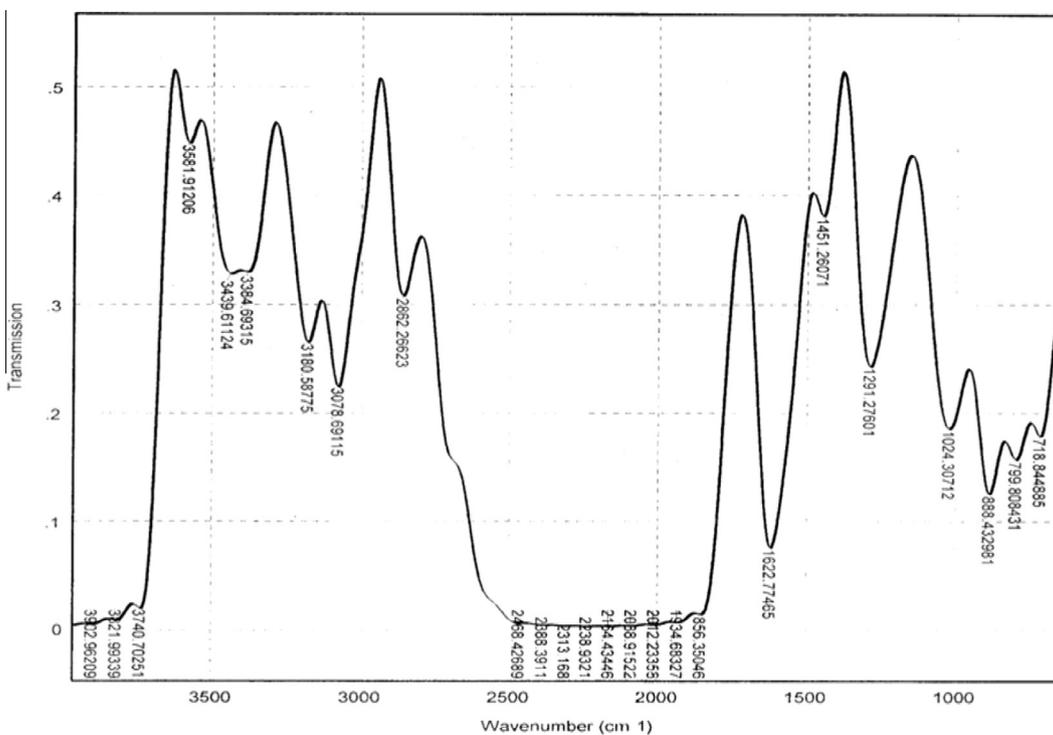


Figure 8 FTIR spectra of alkyd resin.

The measured results are given in Table 6. The abrasion resistance increases with the increase of hardness resins; Resin-B has the highest abrasion resistance as seen from Table 6. For styrenated resins, styrenated resin B has the highest abrasion resistance.

### 3.11. Solubility

Both alkyd resins and styrenated alkyd resins based on palm kernel oil show high solubility in different types of solvents. The solvents used in this test include benzene, toluene, xylene,

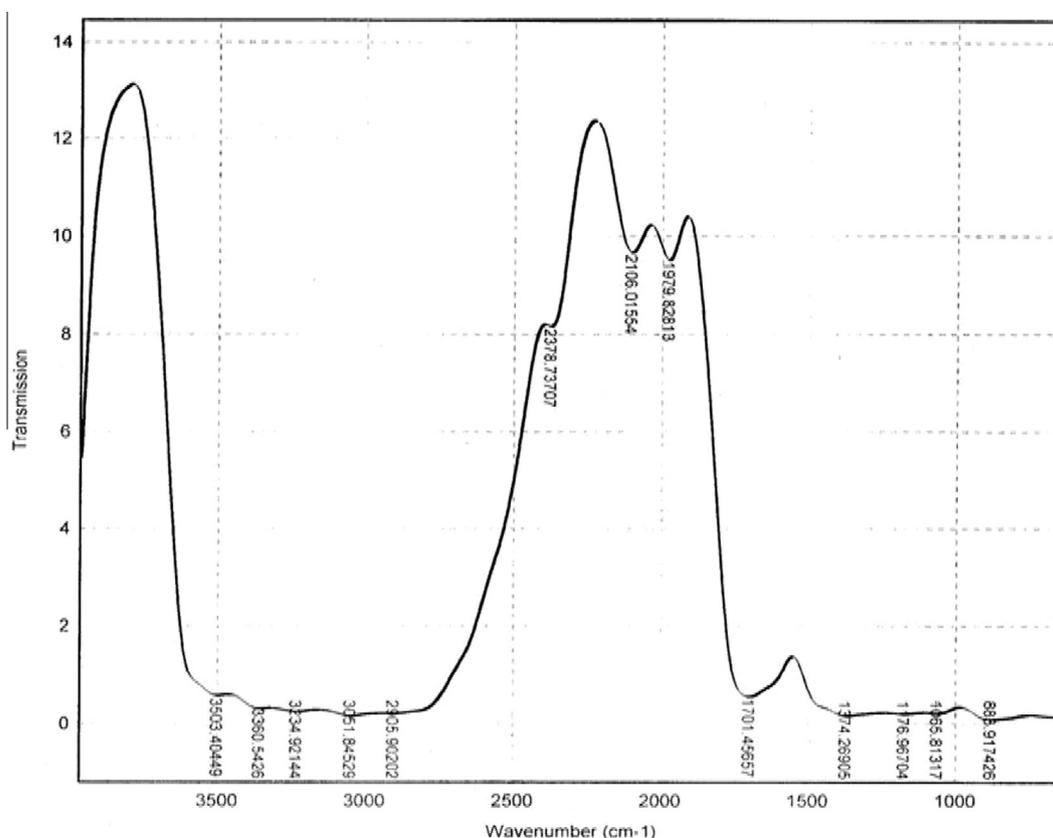


Figure 9 FTIR spectra of styrenated resin.

Table 6 Abrasion resistance values of resins and styrenated resins.

Components	Abrasion resistance ( $\ell/\mu\text{m}$ )
Resin-A	8.60
Resin-B	9.90
Resin-C	9.12
Styrenated resin-A	11.56
Styrenated resin-B	14.28
Styrenated resin-C	13.33

acetone, ethanol and methanol. Solvent molecules increase with the distance between the molecules chains of the resins and styrenated resins. The space between long chains with pendant side group of the resins and styrenated resins are invaded by solvent molecules as they fill the space made available by chain movements. When movements bring two chains close to proximity, short range attractive forces are therefore established resulting in restricted chain movement and thus the formation of a viscous system (Gan and Kim, 1999). Solvents are added to deal with the problem of high viscous resins which is an obstacle in substrate's wet ability. One remarkable observation of the resins and styrenated resins in these solvents is that the alkyd resins dissolve faster than the styrenated alkyd resins. This could be due to the high viscous nature of styrenated resins. This high viscous nature of styrenated resins could be attributed to the high cross linkage in their structure.

#### 4. Conclusion

Copolymerization of palm kernel oil-modified alkyd resin with styrene has been established to have a major improvement on the coating properties of the resultant copolymer. Specifically, the resultant styrenated alkyd resins possessed better chemical resistance. This study also showed that longer reaction time gave a faster drying resin. The FT-IR spectrum confirmed the chemical structures of the raw palm kernel oil, resins and styrenated resins with the functional ester groups present. Therefore, it can be concluded that styrenated alkyds offers an excellent potential applications in surface coating purposes.

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