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Comparative Studies on Alkyd Resins from Palm (*Elaeis guineensis*) Oil and Mango (*Mangifera*) Seed-Oil

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Abstract

Mango seed and palm oils were modified by alcoholysis and esterification process, to form alkyd resin, which is generally used in surface coatings and adhesives. N-hexane was used to extract the mango seed oil, while, palm oil was manually isolated by pressing method after heating to softness. Some physiochemical properties, like, percentage yield, saponification value, acid value, iodine value, refractive index, etc., were carried out according to standards to determine the suitability of the oils in bio-resin synthesis. The colour intensity of the alkyd resins were tested using Gardner scale, elasticity by viscometer, hardness, chemical resistance, and other properties of the alkyd resin were tested according to standard. The Infra-Red (IR) spectra of the raw oils and their respective alkyd resins were determined before modification. Palm oil alkyd resin exhibited a characteristic straight chain of ester functional group at 1738.64 cm^{-1} and aromatic (C=C) ring of ester at 1730.09 cm^{-1} while, mango seed oil alkyd resin showed spectrum of strong peaks at 11698 cm^{-1} with stretching frequency to 1240 cm^{-1}, 1221 cm^{-1}, 1188 cm^{-1}, indicating the presence of a carbon atom single bonded to oxygen. The hardness, glossy tests, drying time, chemical resistance, etc., of the sample alkyd resins compared well to the commercial grade alkyd resin.

Keywords

Mango Seed Oil, Palm Oil, Alkyd Resin, Properties, Alcoholysis, Esterification

1. Introduction

Alkyd resins are thermosetting polyester compounds formed by condensation

reactions between triglycerides or three monobasic fatty acids ($C_{18}H_{37}N$), polyols, (alcohols having two or more hydroxyl groups, such as glycerol $C_3H_5(OH)_3$) and phthalic anhydride (an aromatic dicarboxylic acid $C_6H_4(COOH)_2$).

The quest for under-utilized vegetable oil in the production of alkyd resin has necessitated the approach, to extract mango seed oil and palm oil, and synthesize them to alkyd resin.

These natural resins are the commonest type used by most surface coatings, adhesives, varnishes, printing ink industries, than their petrochemical counterparts, such as, epoxy resins, urea resins, phenolic resins, urethanes resin, etc. These bio-resins are eco-friendly, cheap, available, renewable, and easy to process or use.

Innovations in paint, paper, concrete and binding technology for beautiful architectural appearance and improved life style had increased the over-dependency on the use of synthetic resins from petrochemical compounds. This consequently, has affected our economy negatively, since, petroleum products, which had been the major source of our national revenue.

The call, therefore, is for alkyd resin chemists to explore other under-utilized sources seed oils, and modify them to bio-resins, to meet up with the demand for alkyd resin production, [1]-[5] observed that acid value of finished alkyd resin from rubber seed oil depended on the extent of the esterification reaction. However, [6] researched on polymerization of some less economical seed oils, such as linseed oil, jatropha seeds, sunflower seeds, castor seed oil, and palm kernel seed oil, etc. They discovered, that high grade bio-resins could be synthesised from these seed oils. Notwithstanding, we are embarked on this investigation with intension producing alkyd resin from mango-seed oil and palm oil and compare them to a commercial grade alkyd resin.

Mango seeds which had always been discarded after eating the softy fruits, to litter the environment were considered a resourceful industrial raw materials in the synthesis alkyd resin.

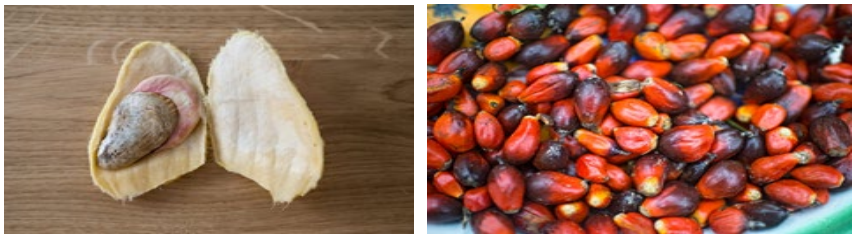
[7] [8] worked on the phytochemical composition of mango seeds and discovered that some the compositions are of good health benefits. They disclosed that mango kernel seeds are potential source of wide range of bioactive and antioxidant compounds, that have cardio or hepatic protective, anti-carcinogenic, and anti-ageing effects.

Palm oil, had been one of the most widely used edible vegetable oil, derived from palm trees and are cultivated in tropical rain forest regions of Africa. They are of several types, but, can yield "non-drying oil" which lack unsaturated functional groups. The oil is used in food manufacturing, in beauty products, and as biofuel. Palm oil accounted for about 33% of global oils produced from oil crops in 2014 [9] Palm oils are easier to stabilize and maintain quality of flavor and consistency in processed foods, so are frequently favored by food manufacturers, [10]. Palm oil consists of about 40% palmitic or hexadecanoic acid $CH_3(CH_2)_{14}COOH$ which a fatty acid with sixteen (16-) Carbon atoms. [3], in their work, suggested

that palm oil can only polymerize by incorporation of a suitable functional group to enable it convert to a drying oil, which can harden to form a film structure. [11], investigated on the acidic values of palm oil and tuna fish oil and observed that, most animal fats or oil could not cure, therefore, is not suitable for surface coating purposes, without modification. [12] discovered the curing process was improved by heating up to 140˚C without using any organic solvent in the presence of methyl ethyl ketone peroxide and cobalt-napthenate.

Modification of vegetable oils, like mango seed oil and palm oil to form alkyd resin had been thought of as a good approach towards sustainability and over dependency on synthetic resins from petroleum crudes. Also, it will minimize pollution due to non-degradability of synthetic resins.

Mango seed is a genus of *Mangifera* which belongs to the family of *Mangifera indica* L., and widely produce edible fruit, with attractive colour and sweet test when they are ripe.



(a) (b)

NB: In (a) (Mango seed) and (b) (Palm fruits), the authors are advised to include a ruler or scale for size evaluation. (the samples are out of season and could not be accessed until January).

Figure 1. (a) Mango Seed; (b) Palm fruits.

Mango seeds, also known as the pitt, is represented in **Figure 1(a)** and Palm oil fruits (**Figure 1(b)**) were the objects of our research. Reports had shown that Mango seeds extract have high concentration of antioxidants, and have lipids rich in unsaturated fatty acids, [13].

Our target therefore is to explore under-utilized seed oils that could be modified, to serve as good source material for local coating industries, other than the over-dependency on petrochemical source materials. This will also help to reduce the huge resources spent on importation of alkyd resin from foreign countries.

The synthetic process of alkyd resin with phthalic anhydride or phthalic acid and glycerine is illustrated in **Figure 2** below.

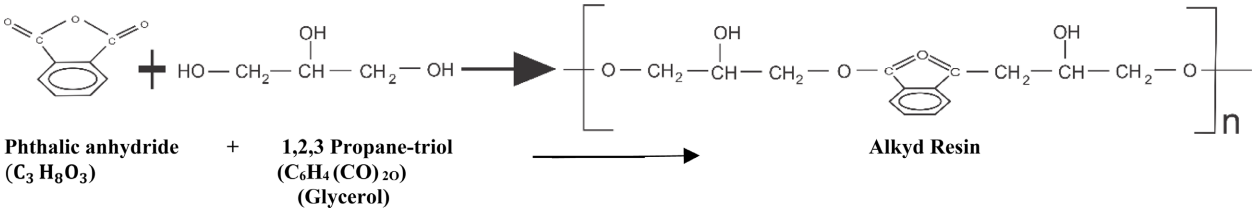


Figure 2. The process of Alkyd resin synthesis.

2. Materials and Method

2.1. Materials

Among the chemicals used in this research are, 5 g of glycerol; 0.2 g of lead oxide (as catalyst); 3 ml of 5 M methanol; 28 g of phthalic anhydride; and 2 ml of xylene, etc. The apparatus and equipment used were 2000 ml electric heating mantle (220 volts); three-necked round bottom flask (500 ml); thermometer; stirrer (40 cm)**;** glass beakers (500 ml)**;** condenser (300 mm)**;** thimble**;** Ohaus digital weighing balance (320 g); manual grinder; viscometer, Fourier Transform Infra-Red Spectrometer (FTIR), etc.

2.2. Preparation of Research Samples

The research samples were palm oil, which is an edible vegetable oil derived from the mesocarp (reddish pulp) of palm fruits and mango seed oil, from seed kernels.

1) Isolation of palm oil from palm fruit mesocarp

The palm fruits were carefully detached using a sharp knife from the large fruit bunch. 2 kg of the palm fruits were washed and cooked until softened. This was pounded in a wooden mortar to separate the seed kernel (endocarp) from the mesocarp, which was later washed with cold water. This mixture was further heated to boiling, until, the oil start to separate. The oil phase was carefully decanted and heated further for an hour to remove the water content. The isolated oil was filtered and transferred into a clean container for further analysis.

2) Extraction of Mango seed oil

The mango fruits (*Dasheri mango*) locally known as German or Sweet mango fruits were picked around Chukwuemeka Odumegwu Ojukwu University environment. The succulent part were removed using sharp knife. The seed kernels were roasted in a drum roaster, the hull removed mechanically and the kernels crushed into small pieces of 0.01 mesh in a hammer mill. 2 kg of the crushed mango seeds were sundried for about 48 hrs to reduce the moisture content, ground into fine powder, dried again for 24 hrs and stored in a desiccators for further studies.

3) Isolation of mango seed oil

The seed oil was later extracted using soxhlet extraction technique at the temperature between 64˚C - 70˚C with n-hexane. The extracted oil was left open to remove excess solvent, before further analysis.

2.3. Characterization of the Oils

Percentage yield of the Oils

The percentage yield of the extracted mango seed oil and palm-oil was determined according Vogel, (2020) and calculated using the formular below:

$$\text{Percentage Yield}(\%) = \frac{\text{weight of extracted oil}}{\text{weight of dry seed powder}} \times \frac{100}{1}$$

2.3.1. Oil Colour Using Gardner Scale

Glass cuvette were filled with 20 ml of the two oil samples and placed in com-

partment of the Gardner Scale. The oil samples' colour were observed respectively, according to (0.5 ASTM Color) standard.

2.3.2. Determination of Refractive Index

Refractive index of the two vegetable oils were determined at 30˚C using Abbe's refractometer. The machine was tuned on, the cell was rinsed with water, followed by acetone and allowed to dry by draining it. The oil was added into the cell and the reading taken respectively.

2.3.3. Determination of Acid Value (ASTM D664)

This was carried out by titrating with phenolphthalein indicator. 7.00 g of the crude oil samples were weighed into two different 250 ml conical flask and 50 ml of 1 M alcohol added to each. Few drops of the indicator was added into 0.1 M sodium hydroxide solution, and agitated vigorously until a permanent pink colour appeared after few minutes.

Percentage free fatty acid was expressed as oleic acid, and was calculated as:

$$\text{Acid Value} = \left(V_{eq} - b_{eq}\right) N \frac{56.1\,\text{g/mol}}{\text{Oil Weight}\left(\text{g}\right)}$$

where: V_{eq} is volume of titrand at equivalent point? b_{eq} is titrant at equivalent point, while; 56.1 g/mol is molecular weight of NaOH.

NB: NaOH is the titrant and Crude oil is the titrand

$$N = \frac{1000 \times W_{KHP}}{204.23 \dfrac{\text{g}}{\text{mol}} \times V_{eq}}$$

where: W_{KHP} is mass (g) of potassium hydrogen phthalate (KHP) in 50 ml of standard solution.

V_{eq} is the volume of titrant (ml) consumed by 50 ml KHP standard solution at the equivalent point, and 204.23 g/mol. is the molecular weight of KHP.

2.3.4. Estimation of Saponification Value

5 g of the each oil sample was weighed into a 250 ml conical flask. 50 ml alcoholic KOH was pipetted into the flask and refluxed for 30 minutes. Allowed to cool and titrated with 0.5 M HCl using phenolphthalein indicator. Blank determination was carried out with same procedure and the value calculated thus:

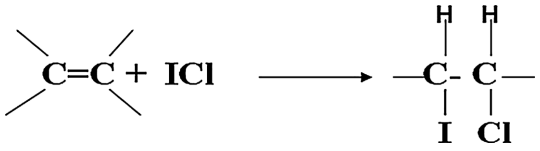
$$\text{Saponification Value} = \frac{28.05\left(B - S\right)}{\text{Weight of Oil}}$$

where B = ml 0.5 M HCl required to titrate blank S = ml of 0.5 M HCI required to titrate sample.

2.3.5. Determination of Iodine Value using Wijs Method

Iodine value is used to determine the amount of unsaturated fats in the oil samples. Iodine is slowly absorbed by oil, but is rapidly taken up by Wijs solution, which consists of a solution of iodine monochloride (ICl) in glacial acetic acid and carbon tetrachloride, as in Scheme 1 below. The unsaturated bonds present took

up the iodine to saturate the double bonds and the remaining unabsorbed iodine is then titrated by means of sodium thiosulphate ($Na_2S_2O_4$).



Scheme 1. Reaction for iodine value determination.

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_2O_4$$

The iodine value was calculated using the expression below:

$$\text{Iodine value} = \frac{(B-S)\times M \times 12.69 \times 100}{W(\text{Weight of oil})}$$

where: B is blank titre of sodium thiosulphate solution (amt. of oil present). S is volume of standard sodium thiosulphate solution required; M is molarity of sodium thiosulphate solution ($Na_2S_2O_3$). W = weight of oil samples and 12.69 is a conversion factor.

2.3.6. Determination of Density or Specific Gravity

Two measuring cylinder (10 ml) were weighed and recorded as W_1. The samples were poured into the cylinders to the mark of 10 ml, weighed and recorded as W_2, mass of samples were the difference between the two. Density is the ratio of mass per unit volume.

2.3.7. Synthesis of Alkyd Resins

100 ml of the oils were poured into two three necked round bottomed flasks and heated to 80˚C respectively, to reduce water molecules or moisture. The modification of the oil samples to alkyd resin was carried out in two stages:

1) Alcoholysis Stage

5 g of glycerol was added to 10 g of both mango seed oil (MSO) and palm oil (PO) in the three-necked flask in the presence of 0.2 g of lead oxide (catalyst) to form monoglyceride. The contents were heated simultaneously to 230˚C, and allowed for an hour for completion. Solubility of 1 ml of the heated samples in 3 ml methanol showed completion of alcoholysis reaction to form monoglyceride. The mixtures were allowed to cool to 140˚C, before esterification stage.

2) Esterification Stage

2.8 g of phthalic anhydride, as well as 2 ml of xylene, were added to the already formed monoglyceride sample mixtures. The mixture was heated to 230˚C for 4 hrs to remove water molecules. The acidity values of the two sample mixtures were determined at interval of 30 mins, until a stable pH drop was achieved for the two samples. The polymerization process was terminated by dipping the reaction system in cold water. Afterwards the already formed alkyd resins were allowed to cool. Some properties of alkyd resin were later determined and compared to the commercial grade.

2.3.8. Physico-Chemical Characterization of the Alkyd Resin

1) Determination of viscosity

Viscosity of the alkyd resins were determined at 30˚C using a viscometer which was rinsed with organic solvent (acetone) and allowed to dry. A small quantity of the resins were added into the viscometer with micro pipette to fill the mark. At the release of each sample, a stop watch was put on and the time taken for the resin to flow from the point of origin to the calibrated mark was noted for the both alkyd resins. These times were recorded and multiplied by a constant factor (0.2483 m^2/s).

2) Test on drying process

The alkyd resins from both palm oil and mango seed oil were dissolved in xylene mixed with drying agents (cobalt napththanate), applied on clear glass panels and allowed to dry at room temperature. The drying process was monitored in terms of time to set-to-touch, surface-dry and hard dry.

3) Determination of chemical resistance test (ASTM D 543 standard)

This was done at room temperature, according to [14]. The end of the glass panels of each alkyd resin films were coated with wax in order to prevent migration of film from the open ends. The panels were then dipped into water, 3 % (V/V), dil. HCl and 1 % (W/V) NaOH. The change in appearance at intervals of 30 mins were noted by recording the first noticeable effect or attack on the glass.

4) Impact strength

The impact strength of the dry alkyd resin films from both oils were determined using tubular impact tester according to ASTM D1709/ISO 7765

5) Solubility

The solubility of both modified palm oil and mango seed oil resin were tested in different solvents, by dropping 1 g of each resin into glass beaker containing 5 ml of each of these solvents; xylene, benzene, toluene, acetone, ethanol and methanol.

6) Adhesion Test

Adhesion of the dried films were tested by using cross hatch test according to ASTM 3359 method. A scope tape was adhered onto the film and peeled off quickly at 180˚ angle. The peeled off grid of areas on the tape were observed by a magnifier.

7) Pendulum hardness

This was done using pendulum hardness tester, to determine the viscoelastic behavior of the alkyd resins.

8) Fourier Transform Infra-Red Spectrometer (FTIR) Test

The bond formations and qualitative compositions of the raw oil and modified alkyd resin samples were carried out using FTIR. Standard interpretation according to the peaks of different absorption spectrum were taken to identify the bonds, organic and inorganic compositions of the alkyd resin samples

3. Results and Discussion

3.1. Physio-Chemical Properties of Our Sample Alkyd-Resin

The results on the percentage yield and other physio-chemical properties of the

two vegetable oils are stated in **Table 1**. The results showed that the values of 6.37% ± 0.012% and 7.51% ± 0.001% for mango seed oil and palm oil respectively are within acceptable yields for most seed oils, according to [15] [16]. We assumed the low yield could be affected by the method of processing and the samples were also randomly selected from the environment. Saponification values were, 218.383 mg KOH/g, and 203.57 mg KOH, for mango seed oil and palm oil respectively and confirmed that they could undergo alkaline hydrolysis to form salt (soap) and glycerol. [17], assured that oils with this percentage yield could be used industrially for production of toiletries and cosmetics. Some researches had proved that long chain fatty acids have low saponification values, because, of reduced number of carboxylic functional groups. [18], emphasized that saponification values of breadfruit seed oil (161.30 mg KOH/g) and soya bean seed oil (191.50 mg KOH/g) also, compared well to our research sample oils. However, they concluded that oil with high saponification value are better for bio-resin production than those with low values.

Mango seed oil (MSO) gave iodine value of 50.91 while palm oil (PO) gave 53.01 as stated in **Table 1**. Toshisada, *et al.* (2021) had suggested that, low iodine values are as a result of high content of saturated fatty acids, while, high iodine values are due to high content of unsaturated fatty acids. Also, some researchers had concluded that oils with iodine values greater than 130 are mostly drying-oil, those between "115 - 130" are semi-drying, while, those with values less than "115" are non-drying oil, [19]. [20] reported that high iodine value of seed oils means high degree of unsaturation and thus more C=C double bond in the molecule. [21], suggested that double bonds are reactive sites for epoxidation reaction in bio-resin production. However, considering the abundant availability of palm oil, mango seed wastes, comparative low extraction cost, and low iodine values, our sample oils had been suggested to be very suitable for bio-resin production. Iodine value is also a good parameter to determine rancidity of an oil, and confirm the shelf life of the oil, therefore, our mango seed and palm oil have concluded to have a long shelf life.The specific density of mango seed oil and palm oil, were 1.09 g/ml and 0.888 g/ml at 25˚C respectively. They also observed the densities of different species of mango seed oil to be within 0.80 to 1.00 g/ml at, 25˚C, while, [3] confirmed palm oil to be 0.9633 g/ml at 25˚C. They suggested that different chemical compositions could be responsible for the differences in the density, although our oils fall within these range. However, the physio-chemical properties of our sample vegetable oils compared favorably well with those reported by [22]), who stated the specific densities of palm oil to be, 0.931 g/ml, hemp seed oil (0.893/ml) and soya bean oil (0.908 g/ml). The acid values as stated in **Table 1**, is 3.31 mgKOH/g for mango seed oil (MSO) and 2.86 mgKOH/g oil for palm oil (PO). Reports had shown acid values of hemp seed oil as, 2.15 mgKOH/g oil and soya bean oil as 1.05 mgKOH/g according to [22]. The high acid value of mango seed oil indicates, that, it has high free fatty acids and carboxylic acid group compared to palm oil, according to [23] [24]. They concluded that, the lower the acid value,

the fewer the free fatty acids, and the low rate of rancidity phenomenon, [25]. We can confirm that the acid values of our research oil samples are low, and therefore, have long shelf life and reduced tendency to spoilage.

Table 1. The physicochemical properties of mango seed oil.

Parameter	Mango seed oil	Palm oil
Percentage yield (%)	6.37 ± 0. 012	7.51 ± 0.001
Saponification value (mgKOH/g)	218.38	213.75
Acid value (mgKOH/g oil)	3.31	5.31
Iodine value (wijs)	50.91	53.01
Peroxide value	15.71	1.50
Density (g/ml)	1.09	0.888
Free fatty acid (%)	1.02	3.71
Colour (Gardner scale)	12	16

NB: % = percentage; g/ml = gram per millilitre; mgKOH/g = milligram potassium hydroxide per gram.

Table 2. Properties of Mango Seed Oil (MSO) and Palm Oil Alkyd Resins as compared to Commercial Alkyd Resin.

Parameter	Mango Seed Oil Alkyd Resin	Palm Oil Alkyd Resin	Commercial Alkyd Resin
Acid value (mg KOH/g	10.20	1.71	10.40
Colour (Gardener Scale)	14	17	11
Viscosity @ 25˚C	448cP	384cP	457cP
Gloss Level	Standard gloss	Fair	Standard
Drying Time (hrs):			
Set-to-touch,	2.30	2 - 4	
Surface-dry	3 - 4	5.30	3 - 4
Hard dry	4-6	5 - 7	5 hrs
Chemical Resistance:			
1% HCl	Fair	Fair	Fair
2% NaOH	Poor	Poor	Poor
Cold Water	Excellent	Excellent	Excellent
Hot Water	Good	Good	Good
Solubility:			
Xylene	Fair	Fair	Fair
Benzene	Fair	Fair	Fair
Methanol	Poor	Good	Good

The physio-chemical qualities of our research sample alkyd resins as compared to the commercial grade sample are stated in Table 2. The viscosity of the resin from mango seed oil showed the value of 448 cP, while, palm oil resin gave 384cP, as against 457cP of the commercial resin. Researches had revealed that, most bio-resins exhibited comparable higher viscosity value than synthetic resins, due to their high molecular weight compositions, [26] [27]. They concluded, that bio-resin with the viscosity within the rage of 100 cP to 1000 cP, is good for surface coatings, gluing, or bonding.

The Gardner scale colour test, showed 14, 17, and 11, for mango seed oil alkyd resin (MSOAR), palm oil alkyd resin (POAR) and commercial alkyd resin (CAR) respectively. The darker colour for POAR could be attributed to the high concentration of fatty acid in the molecule. MSOAR has faint yellow colour, which makes them suitable to reflecting colours, when used in as binders in paint formulations.

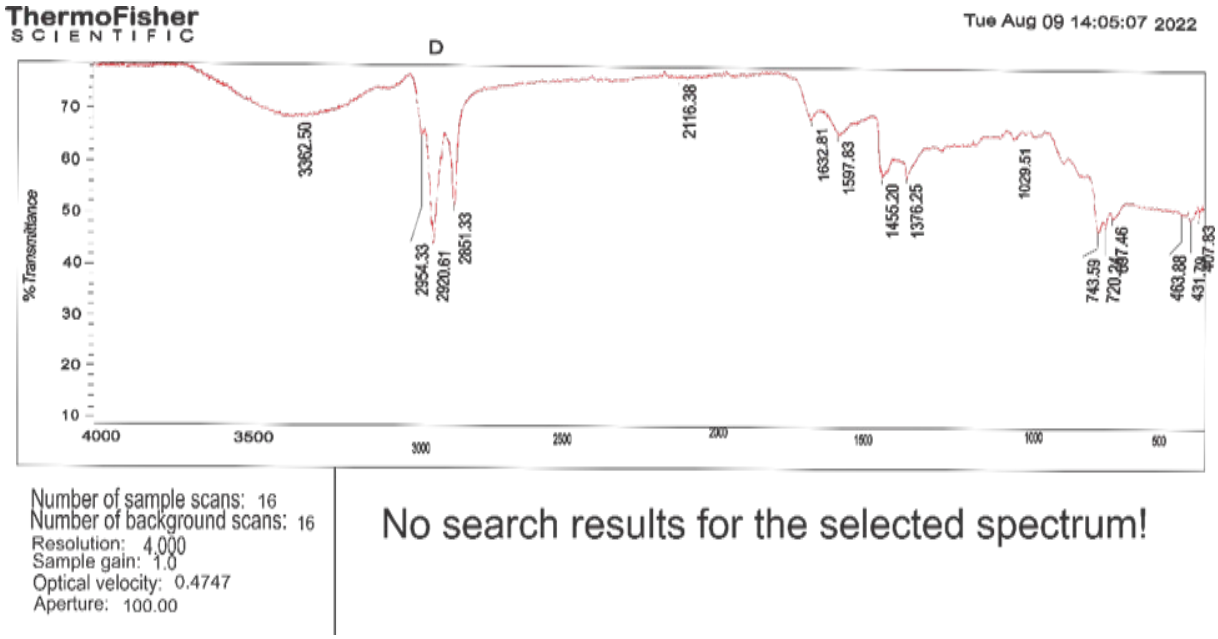
The chemical resistance for the resins were excellent in cold water, poor in base and fair in acid medium, showing that the resins has good coating when applied in surfaces that could be attacked if exposed to acidic or alkaline medium.

3.2. Result of the Fourier Transform Infra-Red Spectroscopy

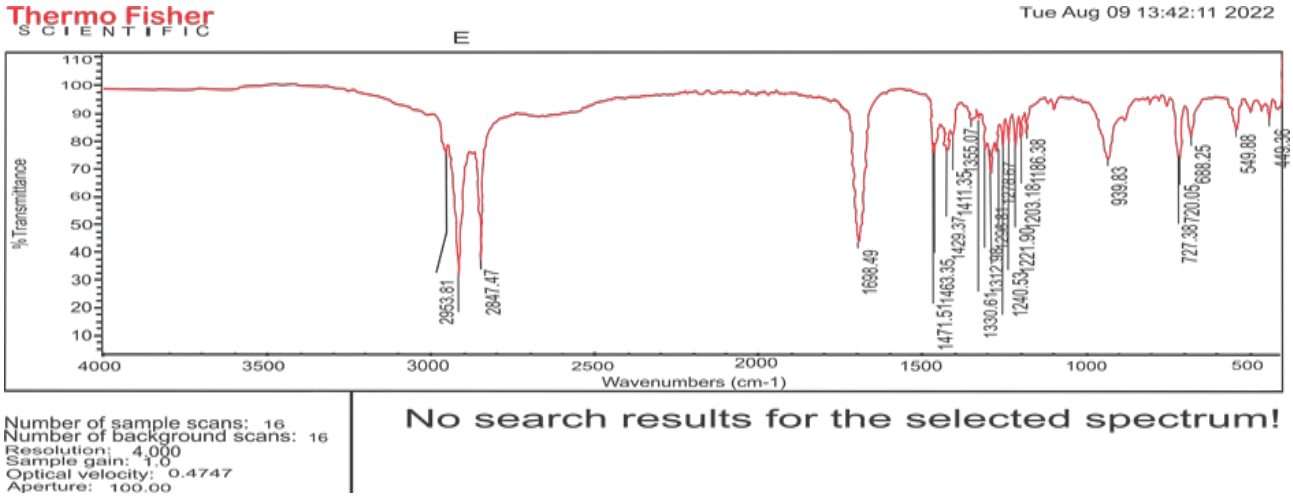
The Fourier Transform Infra-red spectroscopy (FTIR) test was used for identification of compositions of the alkyd resin samples. The absorption spectrum revealed the different functional groups and characteristic bonds between atoms in their various wavelengths within the molecules as shown in Figure 3(a) and Figure 3(b), for MSOAR and POAR respectively.

3.2.1. Result of (FTIR) of the Mango Seed Oil and Its Alkyd Resin Sample

The spectrum finger-prints profile of the raw mango seed oil sample revealed the



(a)



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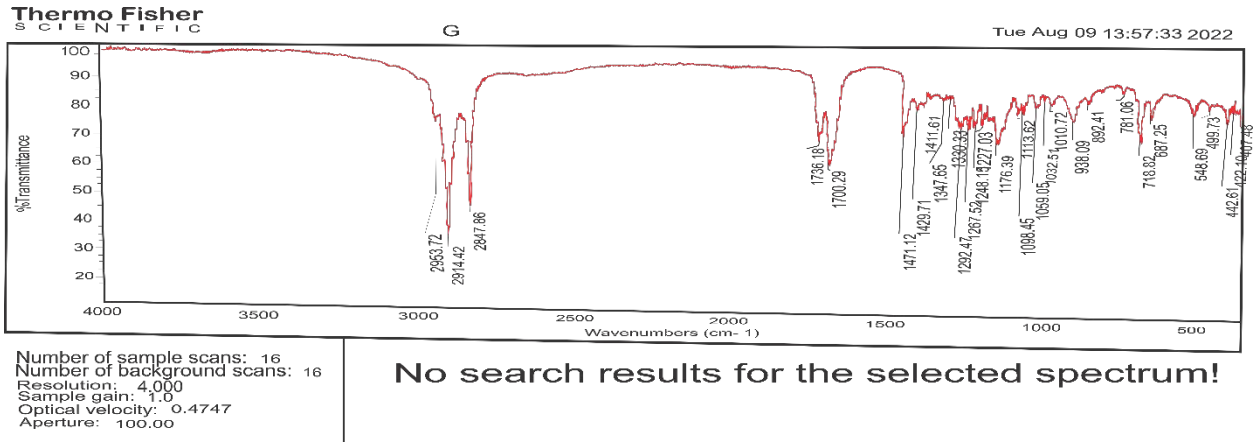
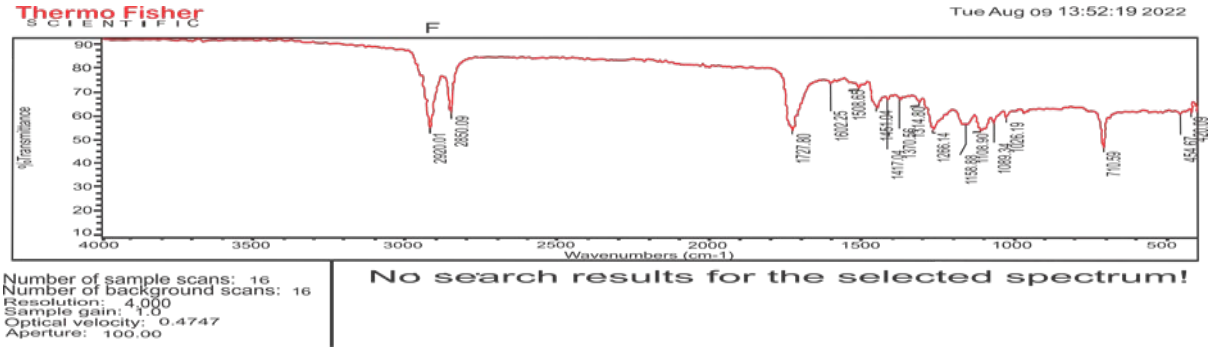


(c)



(d)

Figure 3. (a) FITR Absorption of the Mango Seed Oil; (b) FITR absorption of Mango Seed Oil Modified Alkyd Resin; (c) FITR absorption of Raw Palm Oil; (d) FTIR spectra of alkyd resin from palm oil.

functional groups and bonds, as represented in **Figure 3(a)** Some of the characteristic peaks in the Infra-Red (IR) spectra of the mango seed oil alkyd resin (MSOAR) are represented in **Figure 3(b)**. The spectrum of strong peaks at 1698 cm^{-1} shows formation of an ester bonds C=O, with stretching frequency to 1240 cm^{-1}, 1221 cm^{-1}, 1188 cm^{-1}, indicating the presence of a carbon single bonded to

oxygen C-O. [28] This is in conformation to the findings of absorption wavelength of alkyd resin from Albizia lebbeck (Fry wood) seeds, according to [1]. They observed the peak within the range from 2930.30 to 2933.83 cm^{-1} for the alkyd resin and concluded that the peak height of 1727 cm^{-1} was due to the formation of carbon double bonded to oxygen C=O, and, stretch of unsaturated cyclic ester of monoglycerides. The stretching of 939 cm^{-1} in aromatic carbon bond, C=C indicates the presence of phthalic group in the alkyd resin chain. A complete disappearance of the peak at 2920 per centimeter in the alkyd resin, and the appearance of the peak at 1240, 1221, and 1188 per centimeter indicates that a modification of oil had taken place.

3.2.2. Result of (FTIR) of Palm Oil and Its Alkyd Resin Sample

1) FTIR of Raw Palm Oil

The FTIR spectra of raw palm oil is represented in **Figure 3(c)**. The peak at 3600 cm^{-1} corresponds to the hydroxyl (O-H) of the unsaturated fatty acid in the palm oil molecule. The carboxyl group (C=O) is indicated at 1747 cm^{-1}. The straight chain of -CH- stretch in aliphatic compound is found at band 2854 cm^{-1}. Alkene group (CH=CH) is attributed to band at 3000 cm^{-1}.

2) FTIR of Raw Palm Oil Alkyd Resin

The **Figure 3(d)** represents the IR spectra of the prepared alkyd resin. The absorption spectra exhibited a characteristic straight chain at 1738.64 cm^{-1} and aromatic (C=C) ring ester at 1730.09 cm^{-1}. The absorption band at 3008.99 cm^{-1} is characteristic of alkene group and is in conformation to the findings of [29]. They discovered the peak for their three types of alkyd resins around 1740 cm^{-1} and the stretching vibration for the carbonyl group around 1120 cm^{-1} and 1250 cm^{-1}. The presence of O=C-O-C also exhibited characteristics of ester band at 1125.62 cm^{-1}. The ring ester band at 1730.09 cm^{-1} confirms the esterification of palm oil monoglyceride with phthalic anhydride.

4. Conclusion

The physio-chemical properties of both mango seed and palm oil samples exhibited low iodine values, which showed that, they are non-drying oils, therefore, are suitable to be used in food processing or as edible oil, if further purified. Mango seed oil is from waste seed kernel, which is always affordable, has no economic value, and will help to control adverse health effect from use of synthetic resins, when used as an alternative in alkyd resin formulation. Other characterized parameters for mango seed and palm oils, such as, percentage yields, relative density, saponification values, showed that they can be modified for bio-resin production at commercial level, due to their availability, sustainability, ease of processing and eco-friendliness. Using these oil for bio-resin production will not only give room for alternative resin that is renewable and sustainable, but will also help to minimize over-dependency in petrochemical alkyd resins. The FT-IR spectra confirmed the chemical modification of the oils as indicated in their bonds disclosing

ester functional groups. The absorption bands characteristic of alkene group, peaks and stretching vibration for the carbonyl group concluded the esterification of both palm oil and mango seed oil to alkyd resin using phthalic anhydride.

Outlook

The results from some properties of the research alkyd resin displayed the suitability of the sample to be used as binding material in surface coatings, adhesives, varnishes, printing ink industries, etc. Alkyd resin from natural source materials had been proved to be eco-friendly, sustainable, low cost, than those from petrochemical sources, such as urea resins, epoxy resins, phenolic resins, urethanes resin, etc.

Our target in using under-utilized palm oil and mango seed seeds in the production of alkyd resin has necessitated to extract mango seed oil and palm oil, and synthesize them to alkyd resin.

The characterization of the sample alkyd resin and various results obtained had proved bio-resins suitable alternative as a binding resin for paints, papers, concretes, etc. and binding technology for beautiful architectural appearance and improved life style had increased the over-dependency on the use of synthetic resins from petrochemical compounds.

Limitation of the chemical equation in Figure 2:

- The oil samples were in their liquid states, while the Phthalic anhydride ($C_3H_8O_3$) was in a solid state.
- The two stages of the reaction (First: Conversion of the oil samples which are linoleic acids to monoglycerides through alcholysis using polyol. Second: Esterification of the monoglyceride by addition of phthalic anhydride and xylene.
- The temperature of the oil extraction depends on the type of method used. The methods of isolation of the two seed oils are stated on section 2.2 (i and ii).
- The isolated oil samples had already been used, for the analysis and I could not display the oil samples.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Ezugwu, M.U., Obidiegwu, M.U., Ezugwu, C.H., Ipav, S.S., Dasofunjo, K. and Berinyuy, E. (2019) Synthesis of and Characterization of Alkyd Resin from Albiza Lebbeck (Frywood) Seeds. *Scientific Research Journal* (*SCIRJ*), **VII**, 2201-2796.

[2] Igbo, U.E., Igwe, C.C., Akubueze, E., Ishiola, O.R., Odusote, A.O. and Oyewole, A.O. (2014) Utilisation of Beniseed Oil for the Production of Alkyd Resin. *IOSR Journal of Applied Chemistry*, **7**, 104-106. https://doi.org/10.9790/5736-0753104106

[3] Uzoh, C.F., Onukwuli, O.D., Odera, R.S. and Okey-Onyesolu, C.F. (2013) Synthesis and Characterization of Palm oil Based Air-Drying Alkyd Resin for Surface Coating. *Research Journal in Engineering and Applied Sciences*, **2**, 187-191.

[4] Jack, I. (2016) Comparative Studies of Oil-Modified Alkyd Resins Synthesized from

Epoxidized and Crude Neem Oil. *American Journal of Applied Chemistry*, **4**, 120-124. https://doi.org/10.11648/j.ajac.20160404.11

[5] Ikhuoria, E.U., Aigbodion, A.I. and Okieimen, F.E. (2007) Enhancing the Quality of Alkyd Resins Using Methyl Esters of Rubber Seed Oil. *Tropical Journal of Pharmaceutical Research*, **3**, 311-317. https://doi.org/10.4314/tjpr.v3i1.14615

[6] Norazlina, M.R., Tan, Y.S., Hasmadi, M. and Jahurul, M.H.A. (2021) Effect of Solvent Pre-Treatment on the Physicochemical, Thermal Profiles and Morphological Behavior of Mangifera Pajang Seed Fat. *Heliyon*, **7**, e08073. https://doi.org/10.1016/j.heliyon.2021.e08073

[7] Heiplanmi, R., Manish, S., Sharma, R.R. and Anil, K.S. (2013) Bio-Active Compounds in Mango (*Mangifera indica* L.) and Their Roles in Human Health and Plant Defence—A Review. *Journal of Horticultural Science and Biotechnology*, **88**, 369-379.

[8] Nzikou, J.M., Kimbonguila, A., Matos, L., Loumouamou, B., Pambou-Tobi, N.P.G., Ndangui, C.B., Abena, A.A., Silou, T., Sche, J. and Desobry, S. (2010) Extraction and Characteristics of Seed Kernel Oil from Mango (*Mangifera indica*). *Research Journal of Environmental and Earth Sciences*, **2**, 31-35.

[9] Ritchie, H. (2021) Palm Oil. Our World in Data. https://ourworldindata.org/palm-oil

[10] Raghu, S.V., Kudva, A.K., Rao, S., Prasad, K., Mudgal, J. and Baliga, M.S. (2021) Dietary Agents in Mitigating Chemotherapy-Related Cognitive Impairment (Chemobrain or Chemofog): First Review Addressing the Benefits, Gaps, Challenges and Ways Forward. *Food & Function*, **12**, 11132-11153. https://doi.org/10.1039/d1fo02391h

[11] Indrawaty, D.S. (2022) Formulation of Drying and Non Drying Oil Alkyd Resin from Palm Oil (*Elaesis Guineensis* Jacq.) and Tuna Fish Oil (*Thunnus sp.*) toward Acid Number Value and Non Volatile Content as Surface Coating Resin. *Journal of Vocational Studies on Applied Research*, **4**, 74-79. https://doi.org/10.14710/jvsar.v4i2.16624

[12] Muhammad, R.I., Mohammad, D.H.B. and Saidul, S.J. (2013) Alkyd Resin from Non-Drying Oil. *Procedia Engineering*, **90**, 78-88. https://www.sciencedirect.com

[13] Mutua, J.K., Imathiu, S. and Owino, W. (2016) Evaluation of the Proximate Composition, Antioxidant Potential, and Antimicrobial Activity of Mango Seed Kernel Extracts. *Food Science & Nutrition*, **5**, 349-357. https://doi.org/10.1002/fsn3.399

[14] Momodu, A.S., Akinbami, C.A.O. and Obisanya, J.F. (2011) Achieving Food Security and Climate Change of Mitigation through Entrepreneurship Development in Rural Nigeria: Gender Perspective. *African Journal Environmental Science and Technology*, **5**, 834-854.

[15] Ebrahimian, E., Seyyedi, S.M., Bybordi, A. and Damalas, C.A. (2019) Seed Yield and Oil Quality of Sunflower, Safflower, and Sesame under Different Levels of Irrigation Water Availability. *Agricultural Water Management*, **218**, 149-157. https://doi.org/10.1016/j.agwat.2019.03.031

[16] Si, T., Wang, X., Zhou, Y., Zhang, K., Xie, W., Yuan, H., *et al.* (2022) Seed Yield and Quality Responses of Oilseed Crops to Simulated Nitrogen Deposition: A Meta-analysis of Field Studies. *GCB Bioenergy*, **14**, 959-971. https://doi.org/10.1111/gcbb.12977

[17] Uche, I.C., Chukwujike, I.C. and Nwanonenyi, S.C. (2016) Synthesis, Characterization and Performance Evaluation of Breadfruit Seed Oil Modified Alkyd Resin. *European Journal of Advances in Engineering and Technology*, **3**, 5-11.

[18] Salimon, J., Abdullah, B.M. and Salih, N. (2012) Saponification of *Jatropha curcas* Seed Oil: Optimization by D-Optimal Design. *International Journal of Chemical*

Engineering, **2012**, Article ID: 574780. https://doi.org/10.1155/2012/574780

[19] Suzuki, T., Sumimoto, K., Fukada, K. and Katayama, T. (2021) Iodine Value of Tung Biodiesel Fuel Using Wijs Method Is Significantly Lower than Calculated Value. *Journal of Wood Science*, **67**, Article No. 55. https://doi.org/10.1186/s10086-021-01987-3

[20] Nathan, W.M. (2013) Development of Hemp Oil Based Bioresins for Biocomposites. Master's Thesis, University of Queensland.

[21] Wool, R.P. (2005) Lignin Polymers and Composites. In: Wool, R.P. and Sun, X.S., Eds., *Bio-Based Polymers and Composites*, Elsevier, 551-598. https://doi.org/10.1016/b978-012763952-9/50017-4

[22] Diomande, M., Konan, K.H., Koffi, T.D.M., Gbotognon, J.O., Kanga, K.A., Kouadio, E.J.P., *et al.* (2021) Physicochemical Characteristics and Fatty Acid Composition of Kernels Oil from Four Mangoes Varieties (*Mangifera indica*) (Kent, Brooks, Keitt and Amelie) Harvested, Processed in North of Cote d'Ivoire. *World Journal of Advanced Research and Reviews*, **11**, 102-108. https://doi.org/10.30574/wjarr.2021.11.3.0334

[23] Nursyazana, B.T. and Nazri, M.D. (2014) Production of Bio-Resin from Palm Oil. Bachelor Thesis, University Malaysia Pahang.

[24] Dike, M. C., (2012) Proximate, Phytochemical and Mineral Compositions of Seeds of *Allanblackia floribunda*, *Garcinia kola* and *Poga oleosa* from Nigerian Rainforest. *African Journal of Biotechnology*, **11**, 11096-11098. https://doi.org/10.5897/ajb11.4054

[25] Reeves, J.B., Weihrauch, J.L. and Consumer and Food Economics Institute (1979) Composition of Foods: Fats and Oils. Department of Agriculture, Science and Education Administration, 4.

[26] Elisha, E., Idisis, Y., Timor, U. and Addad, M. (2009) Typology of Intimate Partner Homicide: Personal, Interpersonal and Environmental Characteristics of Men Who Murdered Their Female Intimate Partner. *International Journal of Offender Therapy and Comparative Criminology*, **54**, 494-516. https://doi.org/10.1177/0306624x09338379

[27] Mwesigwa, R., Mwesiagi, J.I., Githaiga, J.T., Nzila, C. and Oyondi, E.N. (2016) The Study of the Affecting Viscosity of Locally Made Bio-Resin from Banana Peels. *Research & Reviews in Polymer*, **7**, 1-10.

[28] Oragwu, I.P., Nwadiogbu, J.O., Okolo, A.J., Enujekwute, C. and Adimnu, G. (2023) Alkyd Resin Syntheise from Mango Seed Oil (Mangier Indica Anacardiceae). *American Journal of Polymer Science and Technology*, **9**, 55-62.

[29] Mohamed, M.A., Jaafar, J., Ismail, A.F., Othman, M.H.D. and Rahman, M.A. (2017) Fourier Transform Infrared (FTIR) Spectroscopy. In: Hilal, N., Ismail, A.F., Matsuura, T. and Oatley-Radcliffe, D., Eds., *Membrane Characterization*, Elsevier, 3-29. https://doi.org/10.1016/b978-0-444-63776-5.00001-2