



Utilisation of *Persea americana* Seed Oil for Solvent-Based Paint Application

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Abstract:

The need for industrial sustainability necessitates the development of bio-based feedstock. The *persea americana* seed was prepared and oil was subsequently extracted using Soxhlet extractor. The result of the physicochemical properties conformed with the literature. Further alcoholysis-modified alkyd process was carried out on the *persea americana* seed oil (PASO) to form *persea americana* seed oil modified alkyd resin (PASOM). The FTIR analysis of the PASOM revealed crucial peaks associated with alkyd resin. This shows that the novel PASOM resin was successfully synthesized. The PASOM resin also shows better resistance with chemical attacks. The characterisation of the solvent-based paint producing using PASOM resin conforms with the standard and shows better performance with chemical media. The PASOM exhibit better performance with adhesion, thereby reduces paint peeling when used.

Keywords: Alcoholysis, alkyd resin, blistering, coating, seed oil

1. Introduction

The increasing global demand for sustainable raw materials and the urgent need to mitigate environmental pollution have driven extensive research into plant-based resources, particularly agricultural waste materials (Aigbodion, and Okieimen, 2001). These bio-based materials offer significant potential for industrial applications, including the formulation of eco-friendly coatings and paints. Paints and surface coatings represent essential industrial products that enhance the quality of human life by protecting surfaces, adding aesthetic value, and improving durability (Akinterinwa *et al.*, 2015). Among various paint formulations, solvent-based paints remain widely preferred due to their superior properties, including excellent flexibility, high gloss retention, and outstanding moisture resistance (Osemeahon *et al.* 2024). The binder constitutes the most critical component in paint formulation, functioning as the primary film-forming agent that determines the coating's performance characteristics.

Alkyd resins serve as the predominant binders in solvent-based paint systems. These resins are synthesized through condensation polymerization reactions involving polyhydric alcohols (such as glycerol or pentaerythritol), polyfunctional acids or anhydrides (such as phthalic anhydride or isophthalic acid), and modifying fatty acids or their triglycerides). The resulting oil-modified alkyd resins account for approximately 70% of conventional binders utilized in surface coating applications. According to Elabor, *et al.* (2023), These resins fundamentally govern critical coating performance parameters, including drying rate, gloss retention, film durability, and resistance to both abrasive wear and chemical attack. The versatility of alkyd resins stems from their compatibility with various polymers and their adaptability through different modification strategies to achieve desired functional properties (Vakili, 2024).

According to Li. *et al.* (2023), alkyd resins are typically classified based on two primary criteria: oil length and oil type. The vegetable oils incorporated into oil-modified alkyd resins are commonly extracted through mechanical pressing or solvent extraction techniques. The classification system for alkyd resins recognizes short oil (approximately 30% oil content), medium oil (approximately 50% oil content), and long oil (approximately 60% oil content) formulations, each exhibiting distinct performance characteristics suitable for specific applications.

The global paint and coatings industry have experienced substantial growth driven by rapid economic development and increasing industrialization, resulting in a significant surge in demand for alkyd resin production (Usman and Ibrahim, 2023). Consequently, substantial quantities of vegetable oils are required for alkyd synthesis. This growing demand, coupled with concerns about resource sustainability and supply chain stability, necessitates the investigation of indigenous and underutilized oil seeds as alternative sources of drying oils. Identifying locally available oil sources with properties comparable to conventionally imported oils can enhance both economic viability and environmental sustainability. In this context, *Persea americana* seed oil emerges as a promising choice for alkyd resin synthesis, offering potential advantages including local availability, renewable sourcing, and suitable chemical composition for paint binder applications. The exploration of such alternative bio-based feedstocks aligns with contemporary trends toward more sustainable coating technologies while potentially reducing dependence on imported raw materials and supporting circular economy principles.

Material and Method

Materials

The materials used for this study includes *Persea americana* seed, n-hexane, FTIR Spectrophotometer, density bottle, alcohol, pigment, kerosene, preservative, extender and drier

Sample preparation

The rotting *Persea americana* (avocado) were collected from fruit market, bypass Yola, Adamawa State, and subsequently transferred to the Chemistry Department, Lab 1 for further processes. The seeds were thoroughly removed, washed with water to ensure no dirt/sands, and subsequently cut into smaller pieces before sundried. The dried pieces were later mechanically grinded into powdery form. The powdery particles were sieved to ensure size's evenly distribution.

Extraction of *Persea americana* seed oil (PASO)

The oil was extracted from the prepared *Persea americana* seed (PAS) powder using the Soxhlet extractor as reported by Ewrierhoma and Ekop, (2016). 10g of PAS was prepared in a filter paper, and tied with thread. The prepared sample was introduced into Soxhlet extractor, with n-hexane as a solvent for the extraction. The oil was separated from the solvent through rotary evaporator, degummed, and the solvent was recovered.

Physicochemical characterization of *Persea americana* seed oil (PASO)

The physicochemical characterisation was carried out on the extracted oil to determine its suitability for alkyd resin synthesis. The following parameters were evaluated using standard analytical methods.

Density, refractive index, and iodine value determination

Density measurements were performed according to AOAC (2022) procedure using analytical balance techniques. Equal volumes of oil samples were weighed in six replicate trials, and density values were calculated from the mass-volume relationship. The refractive index was measured using an Abbe refractometer at 30°C, following standardized procedures. The iodine value, representing the degree of unsaturation in the oil, was determined as the mass of iodine (in grams) absorbed by 100 g of oil. This parameter quantifies the proportion of unsaturated fatty acids present in the oil and serves as an indicator of drying characteristics.

Peroxide and saponification value determination

The peroxide value was measured to assess oil oxidative degradation, as this parameter indicates the extent of oxidation of unsaturated fatty acids upon exposure to atmospheric oxygen (Abdulahi et al., 2017).

The saponification value, defined as the milligrams of potassium hydroxide required to neutralize the fatty acids from complete hydrolysis of 1 g of oil, was determined to evaluate the average molecular weight of fatty acids present. Both analyses were conducted following established analytical procedures.

Alkyd resin synthesis

The alkyd resin was synthesized from *Persea americana* seed oil through the alcoholysis-polyesterification process (Usman and Ibrahim, 2023). The synthesis involved the condensation polymerization of the oil with polyhydric alcohols and polybasic acid anhydrides in the presence of appropriate catalysts. The formulation recipe for alkyd resin synthesis is presented in Table 1.

Table 1. Formulation condition for alkyd resin binder

Ingredients	Amount (%)
<i>Persea americana</i> seed oil (PASO)	50
Phthalic anhydride	30.2
Glycerol	19.8
Mole ratio (Oil:Polyol:Anhydride)	1:1.5:1
Alkyd constant	1.02

Alkyd resin characterization

FTIR spectroscopic analysis

The chemical structure and functional groups of the synthesized alkyd resin were assessed via Fourier Transform Infrared (FTIR) spectroscopy (Agilent Cary 640). Spectra were acquired in the range of 4000-400 cm^{-1} following standard protocols for polymer characterization.

Formulation and characterisation of the solvent-based paint

A gloss paint formulation was prepared using the synthesized alkyd resin as the binder. The paint components were systematically added to the reaction vessel with continuous stirring to achieve uniform viscosity and dispersion. The formulation recipe is presented in Table 2.

Table 2. Solvent-based paint formulation recipe

Component	Amount (g)
Alkyd resin (binder)	50
Extender (CaCO_3)	10
Pigment (TiO_2)	30
Drier (PbO)	5.0
Ethylene glycol	15
Kerosene	15
Diluent (thinner)	5.0
Stabilizers	5.0

Characterisation of the formulated solvent-based paint

The density of the formulated paint was determined using gravimetric methods according to AOAC (2022) standards. Refractive index measurements were conducted using an Abbe refractometer with double prism configuration. Viscosity measurements were performed to assess the flow and application properties of the paint.

Drying time, gloss, and abrasion resistance

Drying time evaluation was conducted following SON (2006) standards. The paint film was applied to a prepared tin plate panel using a paint applicator and allowed to dry under ambient conditions. Surface-dry (dry-to-touch) and hard-dry times were recorded, with target specifications of 6 hours and 24 hours, respectively. Gloss measurement was performed using a gloss meter, with economy gloss paints requiring a minimum gloss reading of 55% according to SON (2006). For water resistance testing, undiluted paint was

applied to a glossy panel at approximately 120 μm wet film thickness and dried for 24 hours. Four milliliters of distilled water were placed on the film surface as circular drops, and observations for blistering, swelling, wrinkling, or cracking were recorded over 30 minutes.

Adhesion and film thickness assessment

Adhesion testing was performed according to the method described by Abdulahi *et al* (2017). The maximum acceptable paint film removal was set at 30%. Dry film thickness was measured following SON (2006) standards, with the target thickness approximately 25 microns.

Chemical resistance

Resin samples were immersed in distilled water, brine solution (NaCl), and 3 M sodium hydroxide (NaOH) solution for 18 hours. Visual observations were recorded to assess the effects of each medium on the resin film, including changes in appearance, blistering, whitening, or film degradation.

3. Results and Discussion

Physicochemical properties of *Persea americana* seed oil

The Table 3 presents the physicochemical result of the *Persea americana* seed oil (PASO). The percentage oil yield was determined to be 19.5% (w/w) demonstrates the seed's potential to serve as an alternative bio-sourced feedstock. Also, the Iodine value for avocado seed oil was reported to be 43.86 g/100g. This is slightly higher compare to 38.35g/100g for avocado seed oil (Otaigbe *et al* 2016) . The low iodine value implied the stability of the oil with oxidation, thus considered as non-drying oil which is suitable for alkyd resin formulation. The acid value of 42.82 mg KOH g^{-1} indicates relatively low in-vivo lipolytic activity and suggests the oil is in a non-degraded state, falling within acceptable limits for industrial applications. Research indicates that oils with low acid values are particularly suitable for paint and varnish manufacture. The free fatty acid content of 0.50% correlates well with the observed acid value, indicating minimal hydrolytic degradation. The saponification value of 230 KOH/g/ suggests the presence of relatively high molecular weight fatty acids, indicating potential suitability for soap production applications. The specific gravity of 0.98 g cm^{-3} and peroxide value of 26.1 meq/kg indicates minimal oxidative deterioration.

Table 3. The Physicochemical properties of PASO

Parameters	Value
Colour	Warm yellow
Percentage of oil yield from the seed	19.5%
Refractive Index	1.466
Relative density of the oil extracted (g/cm^3)	0.98 at 28°C
Acid value of the oil(g/100g)	42.82
FFA	0.50%
Saponification value (mg KOH/g oil)	230
The iodine value of the oil (mg iodine/100 g)	43.86
Peroxide value of the oil (meq/kg oil)	26.1

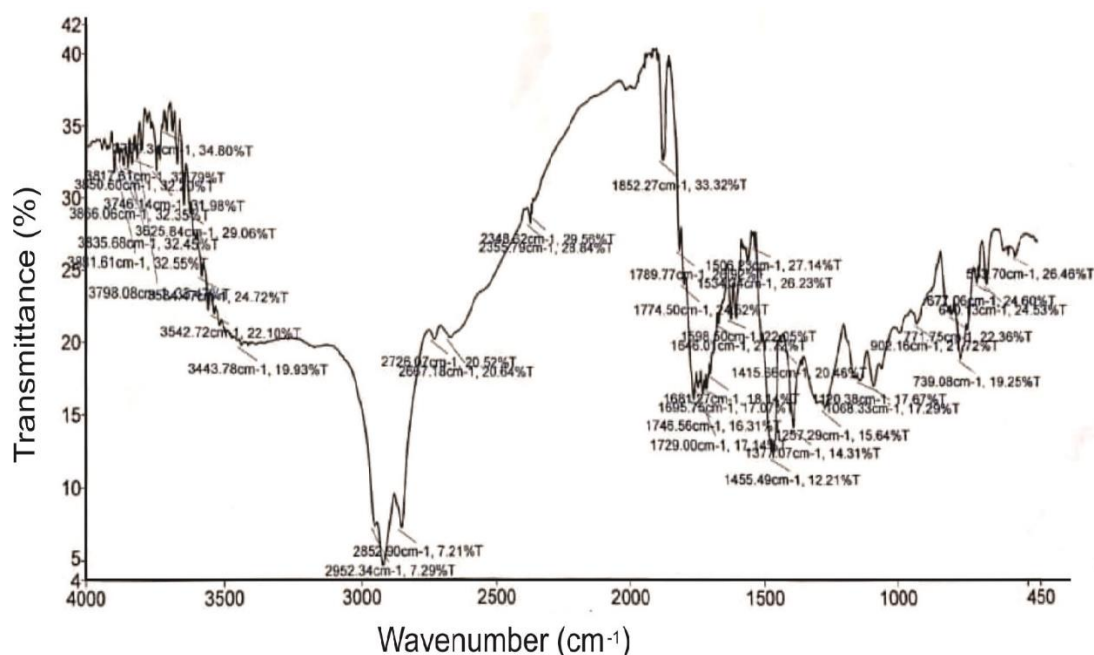


Figure 1. FTIR spectrum of PASO modified alkyd resin

The FTIR spectrum of the synthesized Persea americana seed oil-modified alkyd resin (PASOM) revealed characteristic functional groups confirming successful resin formation (Figure 1). Broad absorption bands in the range of 2854.47-2645.73 cm^{-1} indicate symmetric C-H₂ stretching vibrations from aliphatic chains of the fatty acid moieties (Archibong & Osemeahon, 2019). Sharp peaks at 2340.77 cm^{-1} , 2348.62 cm^{-1} , and 2352.34 cm^{-1} correspond to asymmetric stretching of methyl (C-H₃) groups. The peak at 1455.49 cm^{-1} is assigned to methylene (C-H₂) bending vibrations. Broad absorption bands at 3453.32 cm^{-1} , 3452.72 cm^{-1} , and 3453.32 cm^{-1} are characteristic of hydroxyl (-OH) groups from unreacted carboxylic acid or residual polyol. Strong absorption was observed at 1852.57 cm^{-1} and 1789.77 cm^{-1} which corresponded to carbonyl (C=O) stretching vibrations of ester groups (Babanyaya, et al., 2024). This is the basic linkages in alkyd resins. The peaks observed at 1728.91 cm^{-1} , 1729.00 cm^{-1} , and 1713.86 cm^{-1} are attributed to aromatic ester bands arising from phthalic anhydride incorporation. The peak at 743.78 cm^{-1} indicates C-H₂ rocking vibrations associated with long-chain aliphatic groups. These spectroscopic features are consistent with the expected structure of oil-modified alkyd resins and confirm successful synthesis.

Chemical resistance of alkyd resin

The chemical resistance evaluation results for the *Persea americana* seed oil-modified alkyd resin are presented in Table 4. The resin exhibited excellent resistance to both distilled water and brine solution, showing no visible changes after 18 hours of immersion. However, exposure to 3 M NaOH resulted in blistering, indicating poor resistance to strong alkaline conditions. This behaviour is attributed to the presence of ester linkages in the alkyd structure, which are susceptible to alkaline hydrolysis (Liang, et al., 2022). The alkali-catalyzed hydrolysis of ester groups leads to film degradation and blistering, a characteristic limitation of conventional alkyd resins.

Table 4. Chemical resistance of alkyd resin

Medium	Time (hours)	Effect
Distilled water	18	No effect
Brine (NaCl)	18	No effect
3 M NaOH	18	Blistering

Physical properties of formulated gloss paint

The physical and performance properties of the gloss paint formulated from *Persea americana* seed oil-modified alkyd resin (PASOM) is presented in Table 5. All physicochemical properties, including pH (7.82), viscosity (130 centipoise), and refractive index (1.490), fall within acceptable ranges specified by SON standards for commercial paints. The paint exhibits better adhesion, tackiness, and hardness properties, indicating strong bonding to substrates and appropriate film formation characteristics.

The paint passed resistance to blistering tests, demonstrating good external exposure resistance suitable for environmental conditions including rain and sun exposure. The drying time of 125 minutes meets specifications for oil-based paints (120-180 minutes), with the drying characteristics influenced by the semi-drying nature of *Persea americana* seed oil. The gloss value meets standards for gloss paints, while the viscosity range makes the paint suitable for application by both brush and spray methods. The viscosity, determined by interactions among various paint constituents, significantly affects application and flow properties, which can be thinned with solvent, based on intended application methods.

Table 5. Physical properties of formulated paint (PASOM)

Property	PASOM	SON Standard
Stickiness	Pass	Pass
pH	7.79	7.0-8.5
Adhesion	Pass	Pass
Blistering resistance	Pass	Pass
Viscosity (centipoise)	130	22-150
Glossiness	Pass	Pass
Opacity	Pass	Pass
Flexibility	Pass	Pass
Stability	Pass	Pass
Refractive index	1.490	1.47-1.50

Chemical resistance of formulated paint

Chemical resistance is a critical property determining the stability and durability of coating films after application. The paint exhibited no visible effects when exposed to 0.1 M concentrations of hydrochloric acid, sodium chloride, and sodium hydroxide, as well as distilled water. This excellent resistance to various chemical media indicates that the paint is suitable for practical applications and can withstand diverse environmental conditions. The observed resistance pattern aligns with reported behaviors of other vegetable oil-based paints, suggesting that PASOM paint possesses adequate chemical stability for commercial use.

4. Conclusion

This research successfully demonstrated the utilization of *Persea americana* seed oil-modified alkyd resin (PASOM) for solvent-based paint production. The physicochemical characterization of the extracted seed oil confirmed its suitability for alkyd synthesis, with properties comparable to those reported in scientific literature. A medium oil-length alkyd resin (50% oil content) was synthesized using conventional alcoholysis-polyesterification methodology, incorporating *Persea americana* seed oil, glycerol, and phthalic anhydride. FTIR spectroscopic analysis confirmed the structural integrity of the PASOM resin, revealing characteristic functional groups consistent with conventional alkyd resins. The synthesized resin exhibited good resistance to neutral and weakly acidic/alkaline chemical environments, though showing expected susceptibility to strong alkaline conditions due to ester bond hydrolysis. The formulated solvent-based paint demonstrated excellent physical and performance properties, meeting all relevant SON (Standards Organization of Nigeria) specifications for commercial paints.

The paint exhibited satisfactory adhesion, glossiness, opacity, flexibility, and chemical resistance, with appropriate drying characteristics and viscosity suitable for brush or spray application. These findings indicate that PASOM resin can serve as a viable alternative to conventional imported alkyd resins, potentially reducing production costs while supporting local agricultural economies. The successful utilization of *Persea americana*

seed oil contributes to industrial sustainability by valorising an indigenous, renewable resource for coating applications.

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