# Synthesis And Characterization Of Hydroxylated Sunflower Seed Oil/ Poly Vinyl Acetate Copolymer As A Binder For Possible Application In The Coating Industry

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*Abstract: In this work, a hydroxylated sunflower seed oil (SSO) was synthesized and blended with polyvinyl acetate (PVA) to produce SSO/PVA copolymer binder for emulsion paint formulation. The compatibility of the copolymer at different composition ratios of 100/0, 90/10, 80/20, 70/30, 60/40, 50/50, 40/60, 30/70, 20/80 and 0/100 were studied at $30^0C$. The viscosity, density, turbidity, refractive index, melting point and moisture uptake and solubility in water of the blend were also investigated. It was established that the viscosity, density, melting point, moisture uptake, turbidity and solubility in water decreases with increase in SSO concentration while refractive index and gel time increases with increase in SSO concentration. The result suggest that the problems of hardness, low water resistant and poor gloss traditionally associated with PVA resin can be addressed with SSO/PVA copolymer. The formation of the SSO/PVA copolymer was confirmed by Fourier transform spectroscopy. Comparison of these results with the literature values shows that physico-chemical properties of the SSO/PVA copolymer binder were in conformity. This study may therefore, introduce a novel binder to the coating industry.*

*Keywords: Polyvinyl acetate, Sunflower seed oil, copolymer binder, copolymerization, epoxidation, hydroxylation.*

## I. INTRODUCTION

Nowadays it is difficult to imagine our life without synthetic polymeric materials, as such products are largely used in nearly any field of life ranging from simple packing material over clothing to specialized high-tech devices, e.g. for aerospace engineering and physical and life sciences. The outstanding position of synthetic materials over natural materials arises from their unique versatility, reliability, workability and durability [1].

Polymers are synthesized via polycondensation and by catalytic, ionic or free-radical polymerization (FRP) with a steadily increasing worldwide production exceeding 200 millions of tons per year and an annual turnover (in 2004) of over 70 billion euro in Germany alone (with a worldwide market share of about 8%) [1] The synthetic resins are particularly distinct due to their hardness, durability and resistance to water, alkali and other chemical [2].

Today, the applicability of these polymers has been extended beyond the range that can be obtained from single polymers due to the emerging field of blending. In the years ahead, polymers will continue to grow, and the growth from all indications will be not only from the development of new polymers, but also from the chemical and physical modifications of the existing ones. Eventually, the challenges of recycling posed by environmental problems have led to further developments involving alloying and blending of plastics to produce a diversity of usable materials from what

have hitherto been considered as wastes. Blending of two or more polymers has become an important technique and is a well-established strategy for achieving and improving the cost performance ratio of polymeric products without the need to synthesize specialized polymer system [3]. Polymer blends generate new materials with a combination of properties not found in the pure polymers and blending is often a faster and more effective way of achieving the required properties with reduced cost of an expensive engineering thermoplastic as a determinant factor in load bearing applications [3].

The main advantages of the blended systems are simplicity of preparation and ease of control of physical properties by compositional changes. The concept of blending is about the use of good properties (favorable) of some polymers to correct the deficiencies (unfavorable properties) of other polymers. The process requires different knowledge and techniques than that used to develop new polymers as it requires, less input compared to synthesis of new product. The concept is all about the physical mixture of two or more structurally different homo or copolymers into a single continuous product.

Compatibilization is the process of modification of interfacial properties in immiscible polymer blends. It results in the formation of polymer alloys and is accomplished by physical or chemical means. Blends have traditionally been produced from different thermoplastics and thermosets obtained from both non-renewable and renewable sources.

Oil-based paint is superior to water or emulsion paint in many respects such as water resistant, flexibility, gloss and durability. Oil or solvent paint is made from natural drying oils as binders and hence solvent other than water is utilized for it formulation. Some of the solvents used for its formulation are, acetone, ketone, alcohol etc. This stem from the fact that the drying oils so used are hydrophobic. However, despite the superiority of oil paint over emulsion paint many countries are now threatening to band it usage through appropriate legislation due to it negative effect to the environment [4].

Oil paint produces volatile organic solvent (VOC) on application. VOC depletes the ozone layer of the atmosphere resulting to global warming and hence the negative effect of climate change.

Water paint, although not as good when compared to the oil paint in terms of characteristic, it is environmentally friendly as it evaporates water to the environment on application. This fact has necessitated the need to search for an appropriated paint binder which can challenge the good properties of oil paint on one hand and use water as a solvent on the other hand.

Poly (vinyl acetate) (PVA), is one of the binders commonly used for emulsion paint formulation. However, paints derived from PVA are characterized by poor water resistant, flexibility, gloss and durability. Therefore, if their short comings are to be corrected, the PVA must be modified with a copolymer whose property can make the needed correction in PVA.

Sunflower seed oil is one of the vegetable oils and it is non-drying oil. However, it is hydrophobic, flexible and relative appreciable gloss compare to PVA. Epoxidation and hydroxylation of sunflower seed oil will introduce a hydroxyl (OH) group into the chemical structure of this oil. Therefore, by mixing both the PVA and SSO together, a chemical interaction is expected to occur between the oil and the PVA polymers thereby forming a copolymer of SSO/PVA. The presence of the oil in PVA matrix will introduce hydrophobicity, gloss and flexibility into the SSO/PVA copolymer matrix. Thus, emulsion paint from this copolymer binder will share the good properties of the oil (water resistant, gloss, flexibility) and those of PVA (water solubility, drying, adhesion etc). This is the main trust of this research.

## II. MATERIALS

PVA, Sunflower seed oil, NaOH, HCl, sodium dihydrogen phosphate, sulphuric acid, acetic acid, formic acid, Hydrogen peroxide, $NH_3$, Kaolin, Butanol. Petri dishes, Beakers, Conical flasks, Measuring cylinders, three neck flask, hot plate, thermocouple, condenser, stirrer e.t.c. All materials were used as received. PVA and other chemicals were bought around Jimeta market, Adamawa, Nigeria.

## III. METHODOLOGY

### A. EXTRACTION OF SUNFLOWER SEED OIL

The crushed seeds were manually/traditionally treated with hot water and continuously stirred in other to get the oil.

### B. EPOXIDATION OF SUNFLOWER SEED OIL

The experimental method for the epoxidation step adapted from Goud *et al* [5]

### C. HYDROXYLATION OF SUNFLOWER SEED OIL

The experimental method for the hydroxylation step adapted from Petrovic *et al* [5]

### D. PREPARATION OF SSO/PVA BLENDS AND FILMS

Blend of SSO/PVA was prepared by adding varying amount of SSO in PVA resin. The mixture was stirred and left for 24 h at room temperature (30°C) and then poured into a glass Petri dish for casting. The resin was also allowed to cure and set for seven days at (30°C). The physical properties of the resin films were investigated [6].

### E. DETERMINATION OF VISCOSITY AND GEL TIME

The standard method of viscosity determination was employed using the viscometer bath capillary inserted into the viscometer bath. A 15 ml of the resin was measured and poured into the U-tube viscometer with capillary and then corked. The U-tube was suspended into the viscometer bath containing water and the temperature of the bath was 33°C. The cork was removed and the time taken for the content to run up starting from the top mark to the middle mark was noted using a stop watch. From this result the viscosity of the

sample was calculated. Three different readings were taken for each sample and the average value calculated [7]. Determination of the gel point of the resin was done by monitoring the viscosity of the resin with time until a constant viscosity profile was obtained [6].

## F. DETERMINATION OF DENSITY, TURBIDITY, MELTING POINT AND REFRACTIVE INDEX

Determination of the density of the resin was done by taking the weight of a known volume of resin inside a measuring cylinder and weighed on a weighing balance. The density was then calculated using mass over volume relationship. Three readings were taken for each sample and average value be calculated. The turbidity of the resin samples was determined by using Hanna microprocessor turbidity meter (Model, H193703). Determination of the melting points of the film samples was done using Galen kamp melting point apparatus (Model, MFB600-010F). The refractive indices of the resin samples were determined with Abbe refractometer. The above properties were determined according to standard methods [8].

## G. DETERMINATION OF MOISTURE UPTAKE

Determination of the moisture uptakes of the resin films was done gravimetrically. Known weight of the sample was introduced into desiccators containing a saturated solution of sodium chloride. The increase in weight (wet weight) of the sample was monitored until a constant weight was obtained. The difference between the wet weight and dry weight of the sample was also recorded as the moisture uptake by resin. Three determinations were made for the sample and the average value recorded [9].

## H. WATER SOLUBILITY

The solubility of blend in water was obtained by mixing 1 ml of the resin with 5 ml of distilled water at room temperature (30°C) [9].

## I. FTIR ANALYSIS

The infra-red (IR) analysis of PVA, SSO, and SSO/PVA was carried out using infra-red spectrophotometer (Buck scientific infrared spectrophotometer, Model 530) within 500 to 4000 cm-1.

## IV. RESULTS AND DISCUSSIONS

### A. RESULTS

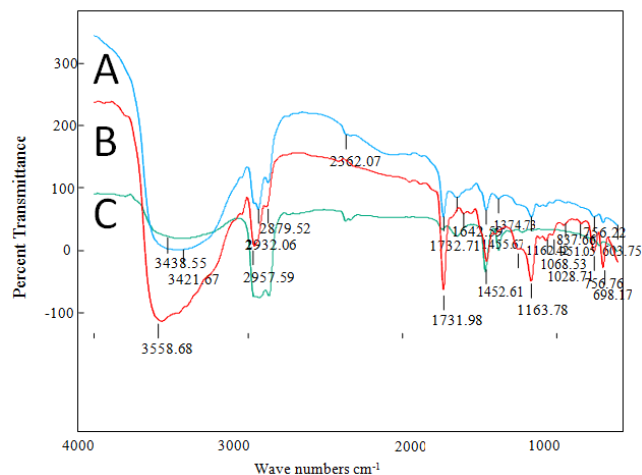a. *FOURIER TRANSFORM INFRARED SPECTOPHOTOMETRIC ANALYSIS (FTIR)*



*Figure 1: FTIR Spectra of (A) Sunflower seed oil/Poly Vinyl Acetate, (B) Poly Vinyl Acetate and (C) Hydroxylated Sunflower seed oil*
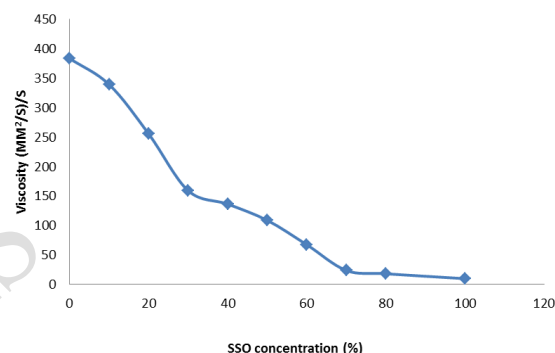


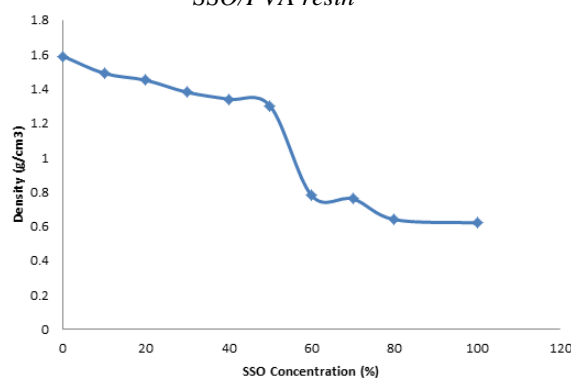*Figure 2: Effect of SSO concentration on Viscosity of SSO/PVA resin*



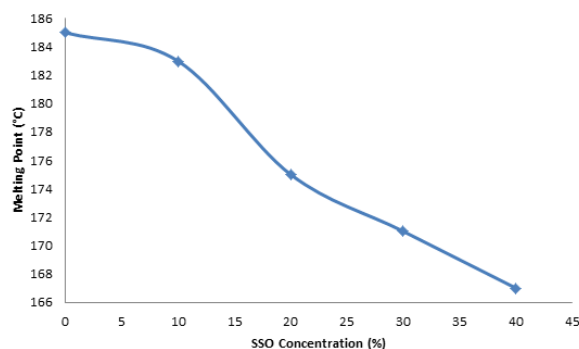*Figure 3: Effect of SSO concentration on Density of SSO/PVA resin*

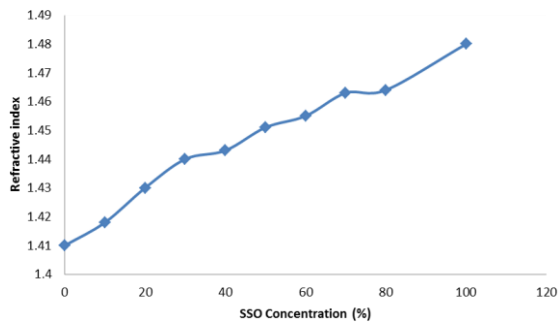*Figure 4: Effect of SSO concentration on Melting point of SSO/PVA resin*



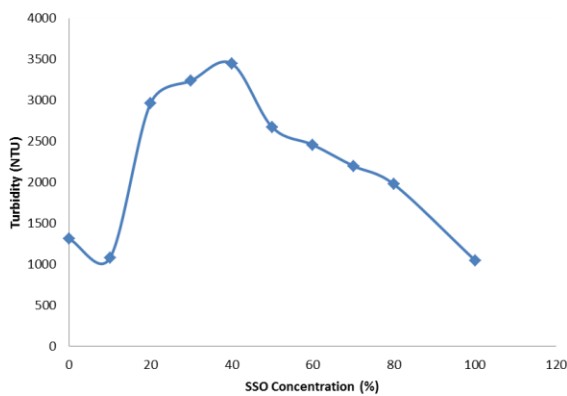*Figure 5: Effect of SSO concentration on Refractive index of SSO/PVA resin*



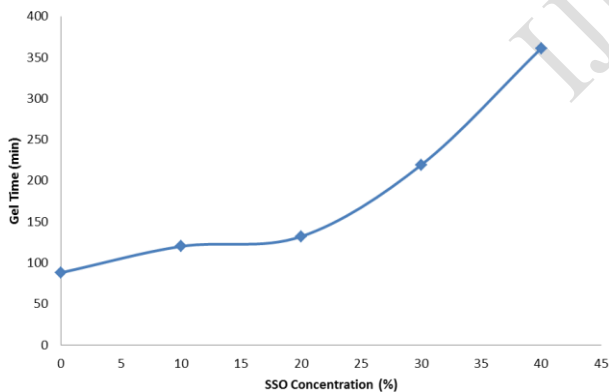*Figure 6: Effect of SSO concentration on Turbidity of SSO/PVA resin*



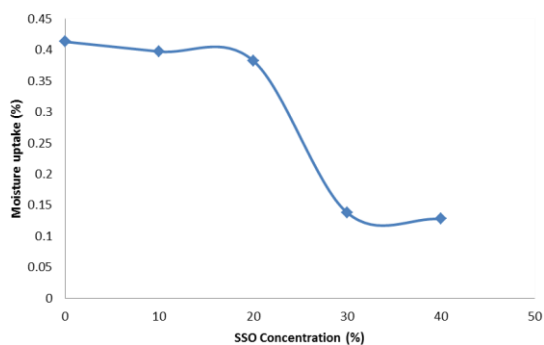*Figure 7: Effect of SSO concentration on Gel time of SSO/PVA resin*



*Figure 8: Effect of SSO concentration on Moisture uptake of SSO/PVA resin*

| SSO Concentration (%) | Solubility Level |
|---|---|
| 0 | Soluble |
| 10 | Soluble |
| 20 | Soluble |
| 30 | Soluble |
| 40 | Soluble |
| 50 | Slightly Soluble |
| 60 | Partially Soluble |
| 70 | Insoluble |
| 80 | Insoluble |
| 100 | Insoluble |

*Table 1: Effect of SSO concentration on the solubility in water of SSO/PVA resin*

| Parameters | PVA | SSO/PVA | Acceptable Level in the coating industry (Osemeahon et al., 2013). |
|---|---|---|---|
| Density (g/cm$^3$) | 1.59 | 1.099 | 1.07 (min.) |
| Refractive index | 1.41 | 1.44 | 1.4000 (min.) |
| Moisture uptake (%) | 0.4129 | 0.1381 | 3.10 (max.) |
| Viscosity (MM$^2$/S/S) | 383.42 | 159.19 | 3.11- 38.00 |
| Melting point ($^0$C) | 185 | 171 | 200(max.) |
| Turbidity (NTU) | 1308 | 3238 | - - |
| Gel time (Min) | 88 | 219 | - - |
| Solubility | Soluble | Soluble | - - |

*Table 2: Comparison of some physical properties of PVA and SSO/PVA resins*

| of Binder | Gel Time (Min) | Viscosity (mm²/s/s) | Refractive Index | Density (g/cm3) | Melting Point (oC) | Moisture Uptake (%) | Turbidity (NTU) | Literature |
|---|---|---|---|---|---|---|---|---|
| SSO/PVA | 219 | 159.19 | 1.41 | 1.38 | 171 | 0.1381 | 3238 | Current study |
| TMU/PS | 120 | 19.70 | 1.4250 | 1.0990 | 262 | 1.01 | 0.0233 | Osemeahon and Dimas (2013) |
| Polyvinyl acetate | ND | 0.40 | 1.40 | 0.929 | ND | ND | ND | Habibu (2011) |
| Commercial UF | 54.2 | 451 | ND | ND | ND | 2 | ND | Suurpere et al (2006) |
| Polyvinyl Butyral | ND | 9-16 | 1.485 | 1.03 | ND | 0.3 | ND | Solutia (2008) |
| Innovative UF | ND | 365 | ND | ND | ND | 0.25 | 0.07 | Zorba et al (2008) |
| UF+UP | 132 | 13.90 | 1.473 | 0.79 | 132 | 4.32 | ND | Osemeahon and Barminas (2007) |
| UF / PE | 190 | 32.60 | 1.432 | 1.3362 | 130 | 0.0080 | 0.0142 | Osemeahon and Archibong (2011) |
| Waste EPS | ND | 500 | 1.464 | 0.84 | 168 | ND | ND | Osemeahon et al (2013) |
| DMU/PS | 1440 | 35.6 | 1.4295 | 1.1953 | 181.42 | 0.26 | 611 | Osemeahon et al (2015) |

*Table 3: Comparison of some physical properties of SSO/PVA film with films from other Paint binders*

## B. DISCUSSIONS

### a. FOURIER TRANSFORM INFRARED SPECTOPHOTOMETRIC ANALYSIS (FTIR)

FTIR spectroscopy has been widely used by many researchers to study the formation of blends [10]. FTIR

spectrum provides information regarding intermolecular interaction via analysis of FTIR spectra corresponding to stretching or bending vibrations of particular bands, and the positions at which these peaks appear depends directly on the force constant or band strength.

Figure 1shows the overlay FTIR spectra of A (SSO/PVA), B (SSO) and C (PVA). In the spectrum of the blend (A), a broad band at 3411.00 cm$^{-1}$ was observed due to the hydrogen-bonded hydroxyl groups that contribute to the complex vibrational stretches associated with free inter- and intra-molecular bound hydroxyl groups [11]; and [12]. The sharp bands at 2868.71 cm$^{-1}$ - 2910 cm$^{-1}$, which is characteristic of C-H stretches associated with the methane hydrogen atoms, was observed [13]. The band at 1732.95 cm$^{-1}$ and was assigned to the C = O stretching of saturated ester [14]. The band at 1456.68 cm$^{-1}$ correspond to the characteristics of C-H of alkane bending vibration and the band at 1162.00 cm$^{-1}$ was attributed to the C-O bond stretching [15]. The absorption bands from 697.80cm$^{-1}$ – 756.74 cm$^{-1}$ were as a result of C-H of alkene bending vibration [16].

In the FTIR spectrum of (B) PVA, shows a dominant band at 3558.68 cm$^{-1}$ that is due to the O-H stretching vibration, different intense peaks such as the doublet of the -CH$_3$ and - CH$_2$ anti-symmetric stretching vibration at 2957.59 cm$^{-1}$ and 2879.52 cm$^{-1}$ were also detected [12]. C=O stretching vibration associated with acetate groups with a molecular vibration at 1731.98 cm$^{-1}$ was detected and complemented by one intense peaks at 1454.61 cm$^{-1}$ due to the -CH$_3$ bending vibration [15]; [14]. Another intense peak was detected at 1163.78cm$^{-1}$ according to the asymmetric stretching mode of - C - O- C- of ester groups, followed at lower wavelengths by a double peak with the maximum at 1068.53 and 1028.71 cm$^{-1}$ [17]. The peaks observed between 698.17 - 951.05 cm$^{-1}$ correspond to the characteristic of sp$^2$ C-H bending vibration [16].

In the FTIR spectrum of (C) SSO, a broad band at 3438.55 cm$^{-1}$ shows hydroxyl stretching vibrations [16]. The broad sharp transmission bands at 2923.22 cm$^{-1}$ produced by stretching of the C-H group of alkane in the spectrum of SSO can be remarkably distinguished.

The peak at 1741.38 cm$^{-1}$ results from the C=O stretching vibrations of the saturated ester present in the oil [15]; [14], sharp band at 1642.67 cm$^{-1}$ correspond to the characteristic of C = C stretching vibration [3]. In the same way, the region of 1375.22 and 11460.22 cm$^{-1}$ of the IR spectrum shows two bands that correspond to the bending vibration of C-H of alkane. The peak at 1155.52 cm-1 is due to C-O-C of ether linkage [17]. The absorption band at 722.47 cm$^{-1}$ corresponds to the characteristic of C-H of alkene bending vibration [16],

Examining the absorption bands for each of A, B and C, it can be seen that there is a shift in the position of the peaks at the O-H bond in the A and C. That is, for pure PVA (B), O-H bond stretching is at 3558.68 cm$^{-1}$ which is shifted to 3411.00 cm$^{-1}$ in the blend (A) and 3438.55 cm$^{-1}$ in SSO (C). The broadening of OH region may be as a result of acidification of the SSO during hydroxylation [14]. However the C = O region of the blends do not show any apparent shift or broadening upon blending, leading to the conclusion that the hydrogen bonding interactions in the blend are qualitatively comparable

to intermolecular interactions present in SSO/PVA. The FTIR techniques pointed out the existence of interaction between the hydroxyl groups of SSO and the hydrogen atom of CH$_3$ group of PVA in the entire SSO/PVA blend.

## b. EFFECT OF SSO CONCENTRATION ON THE VISCOSITY OF SSO/PVA COPOLYMER

Viscometry is a simple and effective technique for monitoring the interactions in polymer blend's solutions [18]. The viscosity of a substance (liquid or fluid) is it's resistance to flow. Studying rheological properties of fluids and gels are very important, since operation processes design depends on the way the product flows through a pipe, stirring in a mixer and packaging into containers [14]. Emulsion lattices has many sensory attributes which are related to their rheological properties, examples are creaminess, thickness, smoothness, spread- ability, flow -ability, brittleness and hardness [19]. The knowledge of viscosity can help to characterize polymers and to determine indirectly molecular mass. The time required for a liquid to drain out of a capillary tube is directly proportional to its viscosity.

Figure 2 shows the effect of SSO on the viscosity of SSO/PVA resin. At the beginning with low level of SSO and high level of PVA, we have relatively high viscosity. Difference in viscosity arose as a result of variation in respective chain length. As the SSO level increased, the molecular weight of the copolymer decreased, this decrease in molecular weight gave rise to decrease in viscosity due to decrease in cross-linking density. This explains the regime from 0-100% SSO concentration. It was well established earlier [20] that the variations of viscosity versus concentration of blend composition plots are linear for compatible blends and nonlinear for incompatible blends. On this basis and in the present study it is noticed that the viscosity varied nonlinearly with the concentration of blend composition. This indicates that the polymer blends of SSO/PVA are found to be miscible when SSO content is up to 30% and then immiscible beyond this composition.

## c. EFFECT OF SSO CONCENTRATION ON THE DENSITY OF SSO/PVA COPOLYMER

Density is a physical property of matter that expresses a ratio of mass to volume and is an important physical parameter in polymer engineering processes. Density depends on the atomic mass of an element or compound. Since different substances have different densities, density measurements are very useful for the identification and characterization of different substances and a significant factor that affects the production cost and profitability of the manufacturing process [19]. The density of paint binder in the coating industry has an important influence on factors such as pigment dispersion, brush-ability of paint, flow, leveling and sagging [6].

Figure 3 shows a gradual decrease observed in density with increase in SSO concentration and may be as a result of differences in the molecular features and morphology which influenced the packing nature of resin molecules as the concentration of SSO increases. Density depends on free

volume and packing efficiency of molecular chains. The reduction in density with increase in molecular weight indicates inefficient molecular packing [21]. It is expected that the density of the blends will fall between the densities of SSO/PVA, since the pure SSO has a lower density relative to pure PVA [22]. The significance of paint binder volume-weight relationship is that, low density favours large volume production, which is a positive gain for the manufacturers/formulators [23].

### d. EFFECT OF SSO CONCENTRATION ON THE MELTING POINT OF SSO/PVA COPOLYMER

Thermal characterization of polymer blends is a well known method for determining the miscibility of polymer blends and melting point of a polymer has a direct bearing on its thermal property ([24]. Melting point of polymer varies depending on molar mass, intermolecular Van der Waal interactions and intrinsic structures that affect the rigidity. This is the mirror of the viscosity behaviour of the polymer composite. In the case of coating industries, the melting point of a binder is related to its thermal resistance as well as to the brittlity [21].

Figure 4 shows the effect of SSO concentration on the melting point of SSO/PVA resin where the melting point decreased sharply as SSO concentration increased. This can be explained on the basis of increase flexibility as a result of increase in the concentration of SSO which gives rise to increase in molecular mobility [21]. The melting points of the two monomers are very different which probably result from different contributing factors. The blend exhibited a broad melting peak in the range of 167-185°C. The polymer blend showed lesser melting temperature as SSO concentration increases. Hence the rigidity of PVA may be reduced via blending it with SSO [24].

### e. EFFECT OF SSO CONCENTRATION ON THE REFRACTIVE INDEX OF SSO/PVA COPOLYMER

Gloss is defined as an angular selectivity of reflectance, involving surface-reflected light, responsible for the degree to which reflected highlights or images of objects may be seen as superimposed on a surface [25]. This test measures the reflectiveness of the paint on the coated substrate. Gloss measurement is dependent on the refractive index of the material and the curvature of the sample [23].

Figure 5 presents the effect of SSO concentration on the refractive index of SSO/PVA resin. It is evident from figure 5 that the refractive index varies nonlinearly with the concentration of SSO. This result is due to differences in the level of specific interaction between the two polymers resulting in molecular weight, molecular features and molecular orientations depending on morphology and crosslink density [23].

Glossiness of the paint shows how it reflects light and shinness. One of the advantages of oil paint is gloss. If water paint is to challenge the oil paint, the gloss property of emulsion paint must challenge that of the oil paint. The refractive index of the binder is a crucial factor in the ultimate gloss property of the paint formulation [26]; [28].

### f. EFFECT OF SSO CONCENTRATION ON THE TURBIDITY OF SSO/PVA COPOLYMER

Turbidity is the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test in the coating industry [27]. The refractive index gives indication of the turbidity. Light interaction with a colloidal system is its turbidity. Turbidity is actually derived its principle from light scattering. When we have homogeneity and few particles, there will be less scattering; hence higher scattering is observed when we have a non homogenous system with a lot of particles [27].

Figure 6 presents the effect of SSO concentration on the turbidity of SSO/PVA resin. Turbidity is relatively low at 100% SSO because pure oil is clear and transparent. On the other hand, at 0% SSO, it becomes a little bit colloidal and light scattering increases. At 10% SSO concentration the turbidity decreased slightly and kept rising until it reaches 40%. As the concentration of SSO increases, the growth of large inter-polymer aggregate increase and the turbidity increased. Increase in turbidity and hence light scattering may be due to the mismatch in the refractive indices of the randomly oriented components in the copolymer composite [27]. It may also be associated with increase in the molecular weight of the copolymer composite and change in the morphology with increase in SSO concentration [26]. However, the turbidity drastically decreased from 50% down to 80% SSO inclusion. Hence turbidity of the system can be used as an indicator of the level of inter-chain cross-linking [27].

### g. EFFECT OF SSO CONCENTRATION ON THE GEL-TIME OF SSO/PVA COPOLYMER

Gels are defined as a substantially dilute cross-linked system, which exhibits no flow when in the steady-state [29]. Gelation is the change in macromolecular structure of resin, which is usually expressed as an increased of viscosity and leads finally to the loss of flow-ability. Gelation has two processes- the initial period of slow viscosity growth and the period of fast structuration [22]. The gel time or pot life is the maximum length of time the system remains in sufficiently fluid condition to be applied to a substrate, it's also the point at which network formation commenced. The dry time of any paint is a function of its binders gel time among other factors. On the technical front, gel time enable paint formulator to ascertain the optimum storage period of a binder before its utilization for Paint formulation and is important in determination of adhesion [29].

Figure 7 shows the effect of SSO concentration on the gel-time of SSO/PVA composite. From the graph, it can be seen that the gel time increased with increased in SSO concentration. This behaviour is attributed to decrease in molecular weight and cross-linking density which leads to decreased in viscosity. This result agrees with the viscosity result where phase inversion and dissociation occurred [22]. In the paint industry, the gel time is typically refers to as dry time of the paint. The longer the time it takes a polymer to gel, the same time it will take for the paint to cure or dry. Short dry

time is drawback to film formation just like if the dry time is too long. This factor must be monitored in order to ascertain the rate it will take a paint formulated from a particular binder to dry [30].

### h. EFFECT OF SSO CONCENTRATION ON THE MOISTURE UPTAKE OF SSO/PVA COPOLYMER

Polymeric binders play a major role in moisture transport properties of paint, because it is one of the major constituent. Waterborne coatings are susceptible to durability issues pertaining poor water resistance [25]. The functional groups on polymers or copolymer resins that are used can undergo hydrogen or ionic bonding, unless the hydrophilic character is balanced with that of the hydrophobic, the coating will either be water sensitive or the formulation will not have colloidal stability. Hydrophobic components in the binder give the best combination of improving water resistance of water-borne coating. A detailed knowledge of moisture transport is also essential for understanding the resistance of a material against attacks from its environment [14]; [31].

One of the main drawbacks of polyvinyl acetate is its high water uptake and this has to be improved in order for the resin to satisfy the coating industry. Water destroys thermo-mechanical properties and adhesion; it induces chemical degradation of the network and also generates stresses, because of swelling and hence blistering of the coating film [22]. The water absorption ratio of latex films is an important parameter for characterization of hydrophobicity of the binder.

As shown in Figure 8, the percentage water absorption of the films was greatly influenced by the SSO content. The moisture uptake decreased with increase in the concentration of SSO, this is as a result of the excellent hydrophobicity of SSO. Increase in SSO into the copolymer give rise to corresponding increase in hydrophobicity of the polymer [32]. This result demonstrated that the SSO/PVA copolymer composite will only hold a very low amount of water, which is an important characteristic of paint formulation [32]. This will also address one of the shortcomings of pure PVA, which is high moisture uptake.

### i. EFFECT OF SSO CONCENTRATION ON THE SOLUBILITY IN WATER OF SSO/PVA COPOLYMER

Solubility is the property of a solid, liquid, or gaseous chemical substance called solute to dissolve in a solid, liquid, or gaseous solvent. The solubility of a substance fundamentally depends on the physical and chemical properties of the solute and solvent as well as on temperature, pressure and the pH of the solution [33]. Water solubility is an important parameter in the consideration of any resin as a binder for emulsion paint formulation. The binders in oil paint are water insoluble, while for emulsion is water soluble.

It can be seen, from table 1, that from 0-40% i.e low SSO concentration, the copolymer is hydrophilic, with hydrophilic PVA dominating (Table 1). This allows it to stay in aqueous solution, but from 50-100% inclusion of SSO, the copolymer seems to become hydrophobic with the hydrophobic now dominating; hence the insolubility in water experienced in this

particular state. This insolubility could also be due to both reduction in the OH groups, and rising of hydrophobic property with SSO inclusion. The insolubility may also be attributed with changes in force of interaction in the copolymer with SSO inclusion [34].

### j. COMPARISON BETWEEN PVA AND SSO/PVA RESINS

The comparison between PVA, SSO/PVA resins and the acceptable level in the coating industry is shown in Table 2. A decrease was observed in density, viscosity, moisture uptake and melting point between the PVA and SSO/PVA; this signals positive developments in terms of film adhesion, flexibility, water resistance and hardness, respectively. The refractive index, gel time and turbidity increased as seen from Table 4, this indicates better gloss, consistency and high ability to withstand weather or service condition. The density and refractive index of both PVA and SSO/PVA are within the acceptable range in the coating industry.

### k. COMPARISON OF SOME PHYSICAL PROPERTIES OF SSO/PVA FILM WITH FILMS FROM OTHER PAINT BINDERS

Table 3 compares some physical properties of SSO/PVA copolymer binder with other paint binders. The viscosity, density, refractive index, melting point, moisture uptake of the SSO/PVA copolymer, are all within the range of other binders. This results place SSO/PVA copolymer resin as a competitive binder among other traditional resins for the coating industry.

## V. CONCLUSION

SSO/PVA copolymer was synthesized by blending polyvinyl acetate with hydroxylated sunflower seed oil. The structure of copolymer was confirmed by FTIR and the effect of concentration of the blends, composition of the blends on the miscibility of SSO/PVA blends were studied, based on, the viscosity, gel time, density, melting point, turbidity, moisture uptake, and refractive index measurements.

The viscosity, gel time, density, melting point, turbidity, moisture uptake, and refractive index measurements of the blending were in agreement with the acceptable levels required in the coating industry. It is concluded that SSO/PVA blend is found to be completely miscible from 0 to 40% while it is immiscible from 50 to 100% composition range. Thus, this resin may be a good paint binder in the coating industry.

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