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Research Article

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Development and Characterization of Polyvinyl Acetate/Soybeans Oil Copolymer Binder for Emulsion Paint

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Abstract In this work, blending of soybeans oil (SBO) with polyvinyl acetate (PVA) was carried out successfully. Some physical properties of the blends were equally studied. Melting point (80^0C-60^0C) and density (1.20 g/cm^3-1.07 g/cm^3) decreased with increased in SBO concentration in the blend. Viscosity increased (2.0 m^2/s) initially before a constant viscosity values was observed (4.20 m^2/s) and a gradual decrease (2.90 m^2/s) with increased in SBO concentration while a gradual increase was recorded for refractive index (36-39) of the blends, with increased in SBO content. The moisture uptake recorded here are within acceptable levels required in the coating industry (3.8 % - 4.9 %) in terms of environmental safety and water resistant. The high refractive index recorded may allow high-gloss coating to be formulated at high pigmentation levels without any deleterious effect on the mechanical or chemical resistance properties of the coating system. The values of moisture uptake, melting point, density, viscosity, pH, drying time and refractive index obtained from this research are within acceptable levels required in the coating industry. Hence it may be recommended as a binder in the coating industry.

Keywords Paint binder, polyvinyl acetate, soybean oil and copolymer, emulsion paint

Introduction

Paint can be defined as a mixture of pigments, binders, and solvents that form a continuous film that can be decorative or protective [1]. Binders can be regarded as a heart of the paint, which are chemical substances that hold the pigment (coloring matter) together [1]. It gives the anchorage and envelops the pigment into a film. Without binder it means no paint formation [1]. Also binders are non-crystalline liquids or solids materials of relatively high molecular weight polymers. They are used in surface coatings to influence the properties of hardness, gloss, adhesion and flexibility. This component carries and then binds particulate components together and provides the continuous film-forming portion of the coating [2].

With the advent of the regulations on air pollution, quality and for safety consideration, there has been continues interests in the search for alternative raw materials (binders) and new formulations to reduce the overall volatile organic compounds, increase flexibility, increase in gloss formation in surface coatings [3]. Therefore if the continuous use of quality paint is to be guaranteed on one hand and the survival of our environment on the other hand in terms of use of paint by man, an alternative polymer (binder) or polymer system must be developed for the coating industry. This polymer should be able to use water as its solvent while at the same time deliver the enamel characteristics of the traditional oil paint. This is the main trust of this particular research. The significance of the research is to add value to present emulsion paint by introducing hydrophobic nature of Soybeans oil into the emulsion paint, which increases resistivity to water, flexibility and reduces Volatile Organic Components VOCs emission, thereby reducing the effect of ozone layer depletion, global warming caused by the emission of Volatile Organic Components (VOCs) from surface coating. Also it will reduce cost, increase quality and develop local technology in the coating industry while increasing environmental health of the society.

Materials and Methods

Analytical grade of polyvinyl acetate, Soybeans oil and distilled water were used. Equipment such as magnetic stirrer, weighing machine, measuring cylinder, test tubes, pH meter and syringe, were provided by the Department of Chemistry, Abubakar Tafawa Balewa University, Bauchi, Bauchi state, Nigeria. All materials were used as provided.

Blend Preparation of PVA/SBO

The method described by [4] was adopted, in which the blending of polyvinyl acetate with soybeans oil was done by preparing 5% soybeans oil in polyvinyl acetate at temperature (30 °C). The solution was mixed thoroughly using magnetic stirrer. The above procedure was repeated at different soybeans oil concentrations (0-35%) and the resulting blend was analyzed. Film of different resins obtained with various SBO concentrations (0-35%) and the physical properties of these films were investigated.

Determination of Physical Properties

Determination of Viscosity

The viscosity of the resins was evaluated using flow cups viscometer expressed in meter square per seconds m^2/s at room temperature, in which the viscosity was recorded from flow time in seconds. Five different readings were taken for each sample and the average value calculated [5].

Determination of Density, Melting point and Refractive Index

The above properties were determined according to [6]. The density of the different resins was determined by taking the weight of a known volume of resin inside a density bottle of (20 cm^3) using Metler At400 weighing balance, the density was calculated using the relationship of mass to volume. Five readings were taken for each sample and the average value calculated. The melting points of the different films samples were also determined by using Galenkamp melting point apparatus model MFB600-010F [6]. The refractive index of resin samples were determined by using ATC hands held refractometer [7].

Determination of Moisture Uptake

The moisture uptake of the different resin films was determined gravimetrically. Known weights of each of the samples were introduced into a desiccator containing a saturated solution of sodium chloride. The wet weights of each sample were monitored until a maximum weight was obtained. The differences between the wet weight and dry weight of each sample were being recorded as the moisture intake by resin [7].

pH Determination

The pH of PVA/SBO (Binder) was determined by using JENWAY 3510 digital pH meter. The pH electrode were standardized with buffer solution of 7 and rinsed with distilled water. The electrode was then dipped into the binder and the pH of the binders was recorded [8].

Water Solubility

To ascertain the solubility of polyvinyl acetate in water, 1ml of the resin was mixed with 5ml of distilled water at room temperature (30°C). A clear transparent solution indicates water solubility while a cloudy solution or white precipitate results in the case of insolubility in water [4].

Dry to Touch

The drying time of the binders was evaluated according to [8] method. Sample of binders were applied on a glass panel with the aid of bar applicator and allowed to dry at 30 °C. Dry to touch were then taken when the binder film was no longer sticking to the finger.

Results and Discussion

Effect of SBO Concentration on the Viscosity of PVA Resin

Figure 1 shows the effect of SBO concentration on the viscosity of PVA resin, which shows a steady increase of viscosity values from 1.98 to 4.26 m^2/s as concentrations of SBO increase from 0 % to 10 %, which means there are strong intermolecular forces and more bonds from the initial stage.

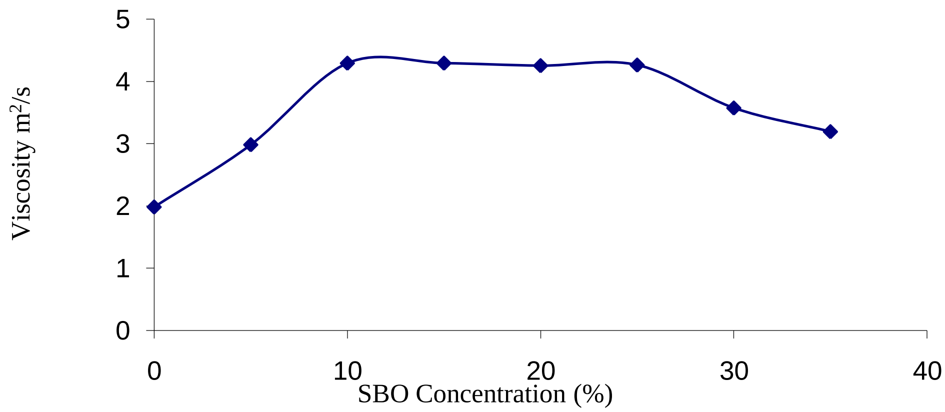

Figure 1: Effect of SBO Concentration on the viscosity of PVA Resin

This phenomenon can be explained in terms of specific interactions between PVA resin and SBO. Also a constant viscosity values were maintained between SBO concentrations of 10 % to 25 %. However, a sharp decrease of viscosity values from 4.26 to 3.19 m^2/s with increase in SBO concentration from 25 % to 35 % was observed.Thisresults from weak intermolecular forces and fewer bonds, which increase the viscosity of the blend solutionto 4.26 m^2/s. However, as the blend concentration increased, the isolated complexes combined and lead to the formation of a gel-like intermolecular complex structure, which lead to the decrease in the solution viscosity of the polymer blend system [9].The result is within the accepted level required in the coating industry.

Effect of SBO Concentration on the Refractive index of PVA Resin

Figure 2 shows the effect of SBO concentration on the refractive index of PVA resin. At initial stage, the refractive index increases from 37 to 43 at 0 % to 35 % SBO concentration.Increase in refractive index was observed with increase in SBO concentration.

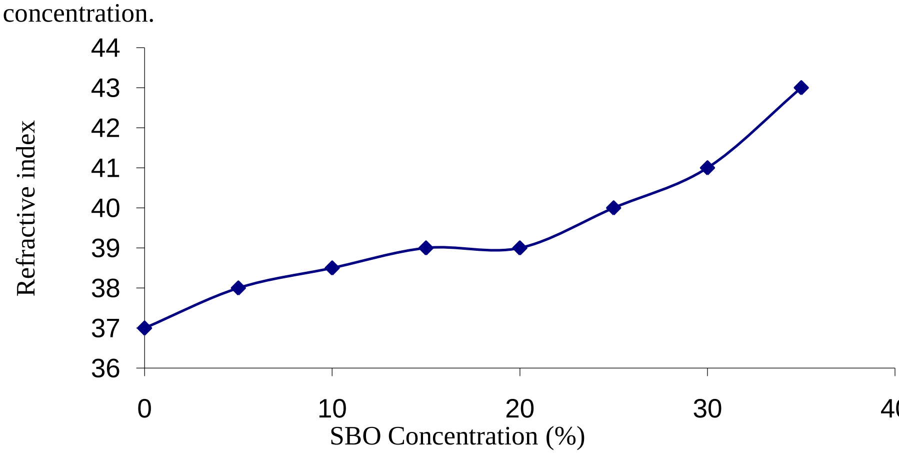

Figure 2: Effect of SBO Concentration on the Refractive Index of PVA Resin

Gloss of a coating with or without pigments is a function of refractive index of the surface. Glossiness of the paint shows how it reflects light and shininess[4]. It is expected that the gloss of the resin increases with increase in SBO concentration. This result may be due to differences in the level of interaction between the two polymers [9] resulting in difference in molecular weight, molecular features and molecular orientations [10].

Effect of SBO Concentration on the Density of PVA Resin

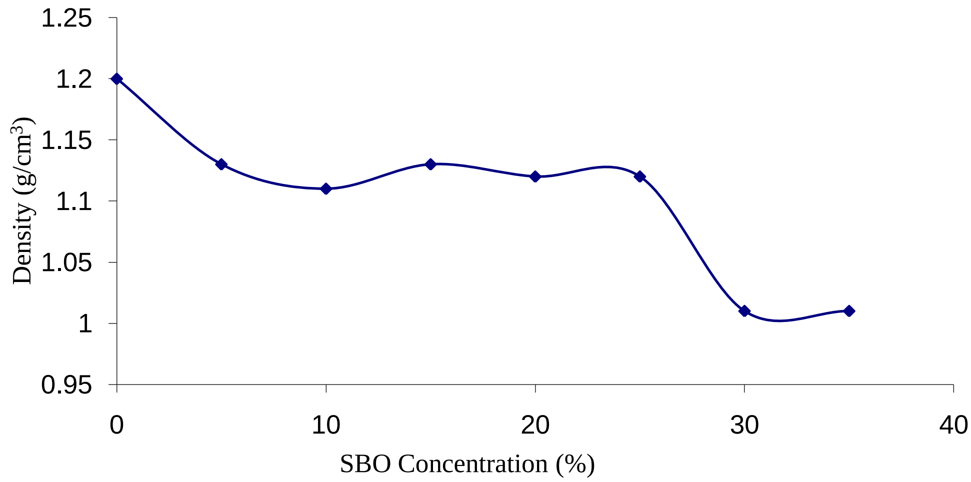

Figure 3: Effect of SBO Concentration on the density of PVA Resin

The effect of SBO concentration on the density of PVA resin is shown in Figure 3, where the density of the binder (PVA/SBO) gradually drops from 1.20 to 1.10 g/cm^3 at 0 % to 35 % SBO inclusion concentration. This means that decrease in density of the resins may be as a result of increase in volume of the binder. This implies that the increase or addition of the SBO affected the volume of the binder than the corresponding mass, thereby insignificantly increasing the mass as the concentration of the SBO increase. The decrease in density of the resin has an important influence on factors such as pigment dispersion, brush-ability of paint, flow leveling and sagging [7]. This trend may be due to differences in the molecular features and morphology which influences the packing nature of resin molecules [11]. The result is within the accepted level required in the coating industry.

Effect of SBO Concentration on the Melting Point of PVA Resin

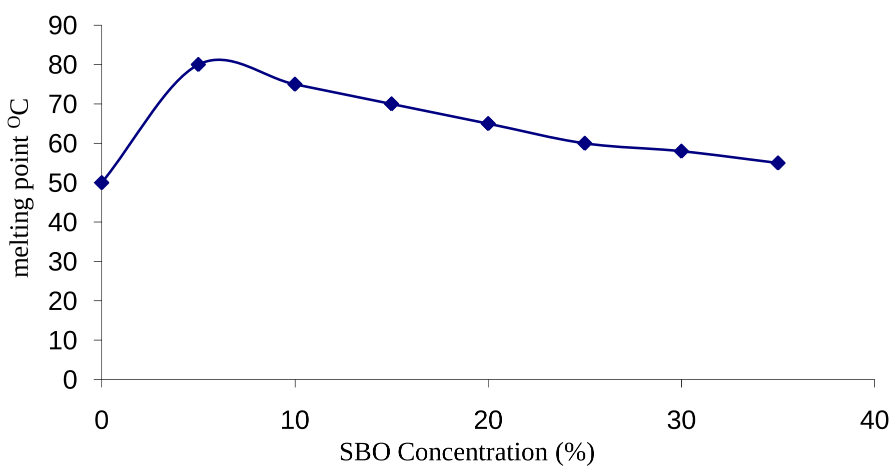

Figure 4: Effect of SBO Concentration on the melting point of PVA Resin

Figure 4 shows the effect of SBO concentration on the melting point of PVA resin. It is observed that the melting point increases from 50^{o}C to 80^{o}C, at 0 % to 5 % SBO concentration which gradually decreases steadily from 80^{o}C to 60^{o}C at 5 % to 35 % concentration of SBO with increase in SBO concentration. Atthe initial stage there are strong specific interactions resulting in the formation of a compact structure thereby introducing some form of hardness to the system [9]. That is at 0 % to 5 %. However, as the concentrations of SBO increase it led to the formation of a gel-like intermolecular complex structure which gave rise to an increase in molecular mobility; hence a reduction in melting point [9]. That is to say more kinetics in the molecular systems of the resin. The result agrees with the work done by [12] which is within the accepted level required in the coating industry.

Effect of SBO Concentration on the Moisture Uptake of PVA Resin

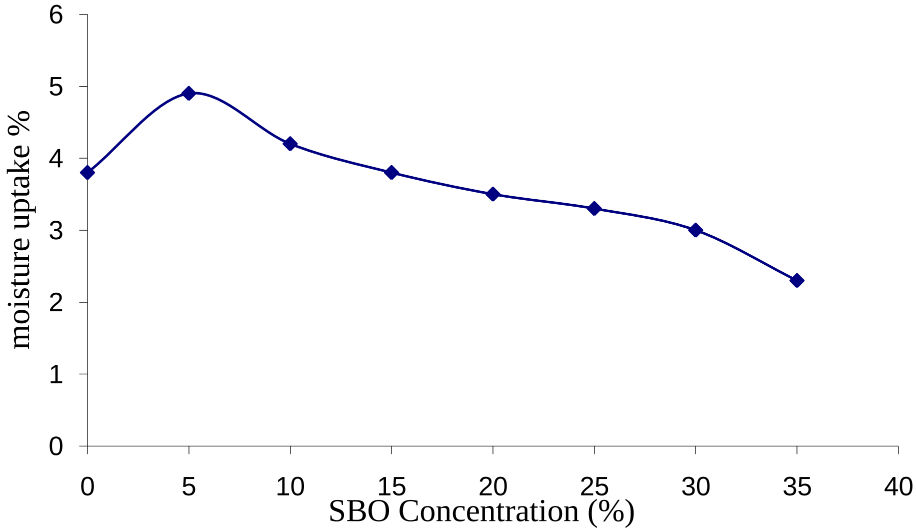

Figure 5: Effect of SBO Concentration on the moisture uptake of PVA Resin

Figure 5 shows the effect of SBO concentration on the moisture uptake of PVA resin. It can be seen that the moisture uptake increases slightly from 3.8 to 4.9 at the beginning (0 % to 5 % SBO concentration) and consistently decrease from moisture uptake of 5 % to 35 % SBO concentration. The different levels of interactions gave rise to polymers with different morphology and crosslink density [9]. From 5% blend, the molecular size holes in the polymer structure were more. After this regime, the size of the molecular size holes might have decreased with increase in SBO loading; hence the steep reduction in moisture uptake. Reduction in moisture uptake can be attributed to the manifestation of the hydrophobic property as the concentration of SBO increases. The hydrophobic nature of SBO is also responsible for this result [9]. The result agrees with the work done by [12], which is within the accepted level required in the coating industry.

Effect of SBO Concentration on the Dry Time of PVA Resin

Table1 shows the effect of SBO concentrations on the dry time of blended PVA resin at room temperature. The result obtained at various SBO concentrations from 0-35 % was due to increase in the viscosity from low viscosity value to higher viscosity value of the resins, which is a consequence of the different level of interaction between PVA and SBO at different blending ratios which results to an increase in the molecular weight and crosslink density [13]. The drying time of the blend increases from 2 to 11 hours with increase in SBO concentrations which is the situation recorded from 0 to 35 %. The hydrophobic nature of SBO may also be responsible for this result. Since as the concentration of the SBO increases there is direct increase in hydrophobicity. Hence, time of drying is proportionally increased. This implies that it will make a good binder for paint. The result agrees with the work done by [12].

Table 1: Effect of SBO on the Dry Time of Blended PVAResin at room temperature

SBO Concentration (%)	Dry to touch (hrs)
0	2
5	3
10	4
15	5
20	7
25	8
30	10
35	11
40	ND
45	ND

ND= Not Determined

Effect of SBO Concentration on the pH of PVA Resin

Figure 6 shows the effect of SBO concentration on the pH of the PVA resin. As shown in the figure, there is a slight increase in the pH 6.8 to 7 of the binder from 0 to 20% SBO inclusion to a neutral system. From the 20 to 35 % SBO, the pH drops and stabilized to slightly acidic medium. This shows that the SBO has a profound effect on the binders. It proves that the SBO is slightly more acidic than the slightly neutral PVA. However, the acidity of the resin agrees with the work done by [14].

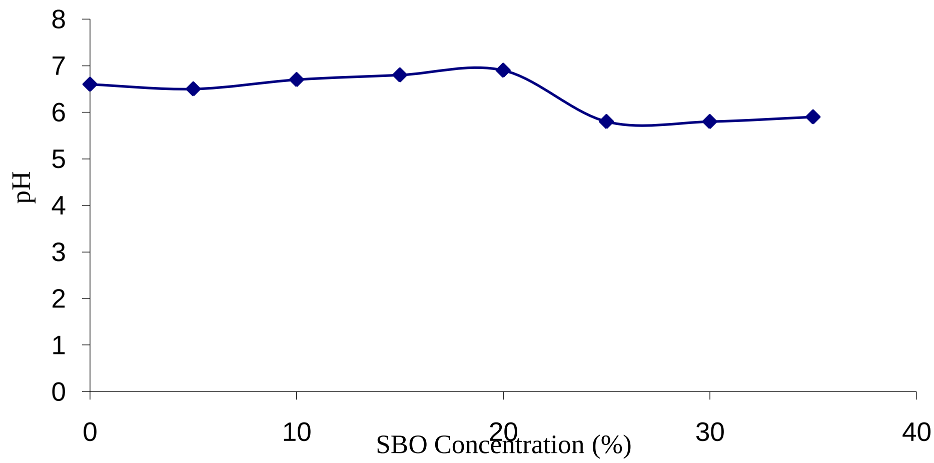

Figure 6: Effect of SBO Concentration on the pH of PVA Resin

Effect of SBO concentration on Water Solubility of the resin

Table 2: Effect of SBO concentration on water solubility of Blended Resin

SBO Concentration (%)	Solubility in water
0	Soluble
5	Soluble
10	Soluble
15	Soluble
20	Soluble
25	Soluble
30	Soluble
35	Soluble
40	Slightly insoluble
45	Insoluble

Table 2 shows the solubility of the blended resin in water at various concentration which shows that they are all soluble in water. Waterborne coatings use water as a solvent to disperse a resin, thus making these coatings ecofriendly, cheaper and easy to apply. In most cases, waterborne coatings contain up to 80% water with small quantities of other solvents, such as glycol ethers, polyvinylchloride etc. These coatings are also known to be environment-friendly as US and European regulations require waterborne coatings to have a VOC content of less than 3.5 pounds per gallon of water [14]. The hydrophobicity of the SBO has not affected the solubility of the resin. However, the findings of the water uptake and drying time have proved the hydrophobicity of the resin/binder which is the desire of this research. The solubility of the binder in water may be as a result of the interaction of the oxygen in the molecule of the binder forming hydrogen bonding with water molecule which may not be observed on the surface of the substrate when the paint is formulated. These shows that it is good for emulsion paint formulation [15].

Conclusion

In this work, blending of SBO with PVA was carried out successfully. The interaction between PVA and SBO showed a remarkable property.Some physical properties of the blends were equally studied. Melting point and density decrease with increase in SBO concentration in the blend. Viscosity increased initially before a gradual decrease with SBO concentration while an initial decrease before a gradual increase was recorded for refractive index of the blends, with increase in SBO content. The moisture uptake recorded here are within acceptable levels required in the coating industry in terms of environmental safety and water resistant. The high refractive index recorded may allow high-gloss coating to be formulated at high pigmentation levels without any effect on the mechanical or chemical resistance properties of the coating system. Thus, this class of resin may introduce a novel paint binder in the coating industry.

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