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Formulation of emulsion paint using benign HGSO/PVAc copolymer as a binder

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ABSTRACT

This study focused on developing a new copolymer binder from Polyvinyl acetate (PVAc) and Guna seed oil, in which the copolymer binder was used to formulate an emulsion paint. The emulsion paint formulated from the novel copolymer binder of polyvinyl acetate- hydroxylated guna seed oil (PVAc/HGSO) was characterised and compared with paint made from conventional polyvinyl acetate (PVAc) binder. Seed oil from guna was extracted mechanically using cold press method, and the extracted guna seed oil were successively subjected to epoxidation and hydroxylation reaction processes. The hydroxylated guna seed oil (HGSO) was copolymerised with conventional polyvinyl acetate in different ratio of 10 to 70% of hydroxylated oil, to formulate a novel PVAc/HGSO copolymer binder. The physico-chemical properties of the formulated copolymer binder were compared with the standard value acceptable in coating industry inorder to ascertain the better blend ratio that will be suitable for paint production. The better blend copolymer binder was used in production of an emulsion paint. The physico-chemical parameters on the formulated emulsion paint were compared with paint formulated using only PVAc as a binder and acceptable value in the coating industry. The novel formulated emulsion paint found to be increased in gloss, adhesion and flexibility, which are major setback in paint produced using conventional PVAc only as a binder. Therefore, the novel PVAc/HGSO can be used to produce an emulsion paint.

Contribution/Originality: This study utilized waste guna seed to solve the problem of poor moisture resistance and poor sheeness associated with paint formulated from the conventional polyvinyl acetate (PVAc).

1. INTRODUCTION

According to Gidigbi, et al. [1]; Akinterinwa, et al. [2] painting and coatings are unique activities that have assisted the human race to contribute meaningfully in earning a better livelihood . Paint not only beautify, but has also helped people to coin a distinguish culture for themselves. It is a true fact that paint has transcended to be an impotant commodity for cultural identity and celebration. Paint has been known to be of great value in building, decorating and spelt symbols in industry. Several studies [1, 3, 4] buttressed that, paint offers an cost-effective protection, conservancy and decoration, including aesthetic and improves functionality to structures. Paint is defined as any liquid, liquefiable, or mastic composition that after application to a substrate in a thin layer, converts to a solid film [5]. Abubakar and Gidigbi [6] reiterated that paints are broadly categorized into two major types, such as water based (emulsion) paint and Oil based paints. According to Udeozo, et al. [7] Oil based paint possess unique qualities such as: good flexibility, low moisture uptake, better glossiness and excellent durability. However, due to the emission of Volatile Organic Compounds (VOCs) from the surface of the substrate, which has been attributed as a contributing factor to greenhouse effect, this has necessitated the reduction in the usage globally [8]. Although, previous studies [9, 10] revealed that water-based paint (Emulsion Paint) was reported to be environmental friendly , since there is no release of harmful substance to the environment, but [2, 5] reported that water-based paint has poor glossiness and high moisture uptake which encourages bacteria activities and overall, affect the durability of the paint. According to Gidigbi, et al. [1]; Gopalan, et al. [11]; Ibrahim, et al. [12] the binder is an essential paint's ingredients, as it is responsible for film formation in paint. Polyvinyl acetate (PVAc) is a major binder used in the formulation of emulsion paint. Unfortunately, binder has been responsible for the drawback in emulsion paint, as it is poor water resistance, and very soluble in water. Therefore, there is a need to develop new binder to compensate for inadequacies in emulsion paint. On the other hand, Barnabas, et al. [13] reported that, Citrullus vulgaris (guna) plant is from a species of the Cucumbitaceae or Cucurbit. The Citrullus vulgaris (guna) was found to be abundant in a study area and also has medicinal and nutritional advantages [14]. Chemical assessment revealed the presence of carbon to carbon double bond in their triglyceride backbone which serve as a site for further chemical interaction. Although few seed oil had been used to modulate polyvinyl acetate, but none has really utilized guna seed oil to improve the performance of polyvinyl acetate. Therefore, guna seed oil is used to modify PVAc inorder to improve the performance of emulsion paint.

2. MATERIALS AND METHODOLOGY

2.1. Materials

The materials utilized for this experimental research include; Guna seed oil, PVAc, Acetic acid, Formic acid, NaOH, HCl, Sodium dihydrogen phosphate, Sulphuric acid, and Formic acid. Others are; Hydrogen peroxide, Kaolin, Butanol, Petri dishes, Beakers, Conical flasks, measuring cylinders, three neck flask, hot plate, condenser. All chemicals are of high analytical grade.

2.2. Methodology

2.2.1. Extraction, Epoxidation and Hydroxylation of Guna Seed Oil

Guna seed oil was extracted manually, according to the method described by Evwierhoma and Ekop [15]. Epoxidation procedure was carried out on the extracted Guna Seed Oil using the method described by Gidigbi, et al. [1]; Osemeahon and Dimas [5]. Hydroxylation procedure was carried out on the epoxidised Guna Seed Oil, using the procedure described by Yelwa, et al. [10]; Petrović, et al. [16].

2.2.2. Copolymerisation of PVAc with HGSO

The PVAc/HGSO copolymer was prepared by carried out various blends (0-70%) of the HGSO in PVAc according to the method described by Gidigbi, et al. [1]; Hwang, et al. [17]; Muhammad and Yelwa [18].

2.2.3. The Physical Properties of the Blended Resin Films

2.2.3.1. Determination of Moisture Uptake, Viscosity and Gel Time

The moisture uptake for the new copolymer binder was carried out gravimetrically using the procedure described by Osemeahon, et al. [14]. Average value of triplicate determinations of each sample was recorded.

2.2.3.2. Determination of Viscosity, Gel Time, Water Solubility and Elongation at Break

Viscosity and gel time determination were carried out according to method described by Abubakar and Gidigbi [6]. Solubility of the resins in water was determined by mixing 1ml of the resin with 5ml of distilled water at room temperature (30°C).

While elongation at break was determined according to the method described by Yelwa, et al. [10].

2.2.3.3. Density, Turbidity, Melting Point and Refractive Index

Determination of density was determined using density bottle of standard volume as described by Gidigbi, et al. [1]. Turbidity was determined using Supertek digital turbidity meter (Model 033G).

The melting point was determined by using Galenkamp melting point apparatus (Model MFB600-010F). The refractive index of the sample was determined with Abbe refractometer. The above properties were determined according to standard methods.

2.3. Paint Formulation

The emulsion paint was formulated according to the method described by Akinterinwa, et al. [2]; Abubakar and Gidigbi [6]; Yelwa, et al. [10].

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Results of the Physical Properties of PVAc/HGSO Copolymer Binder

Table 1 described the physico-chemical properties of a novel PVAc/HGSO copolymer binder, and compared with the PVAc binder and acceptable level in the coating industry.

Table 1. Comparison of physical properties of PVAc and PVAc /HGSO binder.

Parameters	PVAc	HGSO/PVAc	Acceptable level in the coating industry Osemeahon, et al. [14].
Density (G/cm3)	1.211	1.091	1.070 (Min.)
Refractive index	1.400	1.419	1.400 (Min.)
Moisture uptake (%)	0.409	0.221	3.100 (Max.)
Viscosity (Mpa.s)	33.871	23.521	3.11- 38.00
Melting point (°C)	179.0	162.0	200(Max.)
Elongation at break	312.0	391.0	125(Min.)
Turbidity (NTU)	1639.0	1621.0	-
Gel time (Min)	152.0	250.0	-
Solubility	Soluble	Soluble	-

Table 2. Comparison of the physico-chemical properties of PVAc/HGSO copolymer binder with other copolymer binders in literature.

Type of binder	Physical property							Literature
	Viscosity (mpa. s)	Refractive Index	Density (g/cm³)	Melting Point (°C)	Moisture Uptake (%)	Elongation At break (%)	Formaldehyde Emission (ppm)	
PVAc/HGSO	23.52	1.400	1.091	162	0.221	391	ND	This study
UF/PE	32.60	1.432	1.3362	130	0.0080	250.0	0.0142	Osemeahon and Archibong [19]
Palmoil/Alkyd	499	ND	0.929	ND	ND	ND	ND	Mohialdeen [20]
TMU/PS	19.70	1.425	1.099	262	1.01	425	ND	Osemeahon and Dimas [5]
HASO/PVAc	24.11	1.428	1.098	169	0.137	418	ND	Gidigbi, et al. [1]

Note: ND means not detected.

3.1.2. Comparison of the Value of Some Physical Properties of Novel PVAc/HGSO Copolymer Binder and Other Copolymer Binders in the Literature

Table 2 compared the value of some of physico-chemical properties of PVAc/HGSO copolymer binder with other copolymer binders in the literature.

3.1.3. Some Physical Properties of Paints Formulated from PVAc and PVAc/HGSO Binders

Table 3 compared the result of physical properties of an emulsion paint formulated using new PVAc/HGSO copolymer binder with the paint formulated with polyvinyl acetate and the Standard Organisation of Nigeria.

Table 3. Comparison between some physical properties of paints made from PVAc binder and PVAc/HGSO binder.

Parameter	PVAc	PVAc/HGSO	SON standard [21]
pH	7.23	8.09	7-8.5
Viscosity (Poise)	14.9	12.11	6-15
Flexibility	Pass	Pass	Pass
Opacity	Pass	Pass	Pass
Adhesion	Pass	Pass	Pass
Hardness test	Pass	Pass	Pass
Tackiness	Pass	Pass	Pass
Resistance to blistering	Fail	Pass	Pass
Drying time (Min)			
Touch	29	34	20
Hard	41	63	120

Table 4. Chemical resistance of PVAc and PVAc/HGSO paint films.

Samples	Media		
	0.1M NaCl	0.1 M HCl	0.1 M NaOH
PVA	A	B	A
PVAc/HGSO	A	A	A

Note: A= No effect
B= Cracking
C= Blistering

3.2. Discussion

3.2.1. Discussion on the Physico-Chemical Properties of Novel PVAc/HGSO Copolymer Binder

Table 1 revealed the value for the physico-chemical properties of the novel PVAc/HGSO copolymer binder. All the values are within the acceptable range for an emulsion paint binder. Therefore, the new copolymer binder can be subsequently used as a binder in an emulsion paint. On comparison with the PVAc binder, the novel PVAc/HGSO copolymer binder showed improved properties in viscosity, which means better application of paint, high refractive index which means an improve in paint sheeness and low moisture uptake which implies durability [22]. This result is also in consonance with Ibrahim, et al. [12] who investigated the feasibility of using blend of natural rubber with Polyvinyl acetate as a copolymer binder for an emulsion paint. Muhammad and Yelwa [18] agreed that modifying polyvinyl acetate as an emulsion paint binder, has an advantageous benefit to the coating industry. This is further buttressed by Gidigbi, et al. [1] that modified poly vinyl acetate copolymer binder has improved properties such as better flow ability, enhanced sheeness and cost effective. Hydroxylated Guna Seed Oil (HGSO) demonstrates a good compatibility with poly vinyl acetate (PVAc), thereby creating a copolymer binder with better adhesion and excellent cross-linked parameter.

3.2.2. Discussion on the Comparison of Physico-Chemical Properties of Novel PVAc/HGSO Copolymer Binder and Compared with other Copolymer Binder from the Literature

Table 2 showed the comparison of some properties of the novel the novel PVAc/HGSO copolymer binder compared with other copolymer binders from the literature. The novel PVAc/HGSO copolymer binder does not emit formaldehyde, as compared to copolymer of Urea formaldehyde and Polyethylene (UF/PE) binder as reported by Osemeahon and Archibong [19] and urea formaldehyde with polyvinyl acetate (UF/PVAc) as reported by Iqbal, et al. [23]. The novel PVAc/HGSO copolymer binder also has better viscosity compared to monomethylol urea binder reported by Archibong, et al. [24] and improved density reported for blend of Polyvinyl acetate and Hydroxylated Neems Seed Oil (HNSO/PVA) copolymer binder by Muhammad and Yelwa [18]. This showed that paint made from this novel copolymer binder will be flexible on application, with good adhesive property on substrate.

3.2.3. Discussion on Physical Parameters of Paints Formulated from PVAc/HGSO Copolymer Binder

Table 3 revealed the results of physical properties of paint made from blend novel Polyvinyl acetate with hydroxylated guna seed oil (PVAc/HGSO) copolymer binder and the paint made from commercial PVAc. The paint made from the new PVAc/HGSO copolymer binder has high pH value of 8.09 compared with 7.23 from commercial paint. This was as a result of the presence of hydroxyl group in the novel PVAc/HGSO binder. The pH value is usually used to create buffer solution in paint inorder to minimize the growth of microbes [25]. the pH of this study is within the range of Standard Organisation of Nigeria (SON), and also in consonance with that of paint developed from Hydroxylated Avocado Seed Oil/ Polyvinyl acetate (HASO/PVAc) copolymer binder reported by Gidigbi, et al. [1]. Also, the paint from novel PVAc/HGSO copolymer binder has lower viscosity of 12.11 poise compared to 14.9 poise from commercial paint. This indicate flexibility, smoothness and better consistency [11]. Both are within the acceptable range of Standard Organisation of Nigeria. Although, the drying to touch time of the paint made from novel PVAc/HGSO copolymer binder exceed SON stipulation, due to the presence of lipophilic nature of hydroxylated guna seed oil, but fall within the SON range for drying hard. Also, slow drying prevents cracking during the cross-linking process of paint. The paint developed from novel HASO/PVAc copolymer binder passed tackiness assessment. This indicates the good adhensibility of paint to substrate [26]. The paint produced from novel PVAc/HGSO passed the test of blistering, while commercial paint failed. This may be connected to the presence of hydrophobic component in the copolymer binder formation, as the hydroxylated seed oil presence in the novel copolymer binder is semi-hydrophobic, thereby addressing one of the major shortcoming of conventional paint, which is poor water resistance [3].

3.2.4. Discussion on Chemical Resistance Property of the Paint

Table 4 revealed the chemical property of the paint formulated from both novel PVAc/HGSO and PVAc. According to Abubakar and Gidigbi [6] chemical resistant is one of the major determinant of usability and durability of paint. It is a measured of ability of paint to resist chemical interaction that may lead to discolorisation. This is known as wash-ability resistance. According to Ibrahim, et al. [12] the higher the washability resistance, the better the quality of the emulsion paint. The paint made from the novel PVAc/HGSO and PVAc were exposed to salt, acid and alkaline solutions. While commercial paint produced from PVAc passed salt and alkaline solution, but was fairly affected by acidic solution. Meanwhile, the chemical integrity of paint made from the novel PVAc/HGSO copolymer binder were not compromise when exposed to salt, acidic and alkaline medium. This may be due to excellent cross-linking network which inhibit interaction with other external factors , thereby causing it to last longer [27, 28].

4. CONCLUSION

The copolymer PVAc/HGSO binder was successfully synthesized by blending polyvinyl acetate with hydroxylated guna seed oil. The best ratio of blend chosen for the production of novel PVAc/HGSO was based on the alignment of important parameters with the acceptable value in the coating industry. The best ratio for the novel copolymer comprises 20% of HGSO and 80% of PVAc. This novel copolymer binder showed better viscosity, good water resistance and excellent refractive index compared to common PVAc binder. The emulsion paint formulated using PVAc/HGSO binder indicates a good consistency, smoothness and uniformity. It also addressed a major shortcoming in commercial emulsion paint by resisting blistering and demonstrate excellent chemical integrity by resisting discolorisation in salt, acidic and alkaline medium.

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