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PROCESS FORMULATION AND USAGE OF CASTOR SEED OIL AND POLYVINYL ACETATE ADMIXTURE IN THE MANUFACTURING OF EMULSION PAINT

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ABSTRACT

Paints are widely used for surface coating, they are made with combinations of different raw materials, for example polyvinyl acetate. The cost of this raw material is increasing daily in Nigeria due higher exchange rate of dollar to naira coupled with an increasing number of entrepreneurs using this material for paint production daily. This raw material is synthetic and not eco-friendly. Therefore, this research seeks to fill this gap by using natural material (castor seed oil) that is cheap and eco-friendly as combinatorial with polyvinyl acetate. Castor seed oil used for this research was sourced from a local market in Delta State. Castor seed oil was extracted using solvent extraction. Paint was produced using four different formulations; Paint produced was characterized using ASTM method. Results obtained from the work showed 43.5 yield of castor seed oil, results of opacity, viscosity, specific gravity, drying time and pH are in the range of 9.5-22, 0.92-0.94,1.01-1.15 gcm^3, 25-30 minutes, 7.9-8.6 respectively. The combination of 60% Polyvinyl acetate to 40% Castor seed oil was more effective for paint production due to its low viscosity (0.92^{0}C) and high specific density (1.15 kg/L). Therefore, 60% Polyvinyl acetate to 40% Castor seed oil combinatorial is recommended for paint production for economic and environmental gain.

Keywords: Paint, polyvinyl acetate, castor seed oil

INTRODUCTION

Paint is a synthetic substances used for coating and was traditionally used to portray pigmented materials as distinct from clear films which are more properly name as lacquers or varnishes (Lambourne, 1988). Paints and coatings can be categorized into the following major classes; architectural coatings, product coatings for original equipment manufacturers and special- purpose coatings (Dean,1991).The raw materials generally used for the manufacturing of emulsion house paints include; prime pigments, solvents, extenders, binders and additives (Abdulsalam and Yahaya, 2010). Researchers have shown that modern paints had been formulated to add shape, elegance, quality and durability to both exterior and interior finishes in automotive vehicles by incorporating plasticizers (David & Christopher, 2000). They are dispersants or additives that could raise the plasticity, flexibility, compatibility, washability and durability of auto-paint or gloss paints in general. Studies have shown that plasticizers have been used to improve the strength of glass-fiber-reinforced plastic motor cases, concrete clays and related products (Wollensak*et al.,* 2003).However, despite the dominance of oil paint over emulsion paint many countries are now threatening to ban its utilization through appropriate legislation due to its adverse effect on the environment (Osemeahon, 2016).

Environmental agencies of government had advised automotive paint companies to decrease solvent emission in their paint commodity to check-mate air pollutions (Needs *et al.,* 1995). mixing of clay, animal fats with chalk was the earlier technology of paint marking. By 2500C the Egyptians had enhanced on this technology considerably (JEPER, 2014). Now, in the twentieth century, the chemistry of many aspects of paint production and function is understood, meaning that paint production has finally moved from being a science (JEPER, 2014).

Paints are product used for colouring and protecting many surfaces, including houses, cars, road markings and underground storage vessels. Paint is essentially composed of a binder, pigment, and solvent (Allans & Dlant,1984).

paint is a liquid- engineered product made of several different ingredients that mix to create a specific product with its unique properties (Rodger, 2008). The selection of components used to produced paint will affect its stability (shelf life), application characteristics, handling, cleanup, disposal, and most importantly, the performance of the product on which it is applied. Paint formulations usually include; resin (binder), pigments, solvents and additives.

Proper paint formulations depend upon feedstocks selection and accurate calculation of the amounts of ingredients.

The value for non-volatile ingredient in the paint is obtained from the product of weight % of resin used in the paint and its total solids content. The PVC values for various coatings are as follows: flat paints, 50-70%; semi-gloss paints, 35-45% and gloss paints, 25-35% (Sharma 2011). Generally, the paint gloss reduces as the PVC increases. This is because when the volume of pigment increases relative to the non-volatile vehicle, gloss decreases until the gloss of the paint becomes flat (Sharma (2011). The viscosity of paint, which is also controlled by the PVC, is an important quality characteristics as it affects the flow and application properties of the paint.

Castor seed oil (*ricinius communis oils*), as one of the drying vegetable oil is obtained from the castor oil plant seed of the family Euphorbiaceae. It is one of the most widely used film-forming oils with uses in decorative and surface coatings. The oil is afamous None-dible oil with important industrial and medicinal value. Castor oil displays the most unusual physical and chemical properties due to the presence of ricinoleic acid in more than 87% of quantities. The four functionalities, namely carboxylate, hydroxyl, unsaturation, and long-chain hydrocarbon, present in ricinoleic acid made this molecule unique in the chemical world. Due to this uniqueness, castor oil has become a potential alternative to petroleum-based products and also an excellent candidate for exploitation in biorefinery mode as it is completely biodegradable and renewable feedstock. Castor oil has many uses such as specialty soaps, adhesives, surfactants, cosmetics and personal care products, wax substitutes, inks, perfumes, plasticizers, paints and coatings, a variety of lubricants, and greases, as well as in food, fine chemicals, and pharmaceuticals companies.

The presence of ricinoleic acid (a mono-saturated compound) with 18- carbon fatty acids having hydroxyl groups on the 12th carbon makes derivatization of other compounds like alkyd resins possible. It is one of the drying oil that could cross-link on exposure to air to form a solid dry film, a property that makes it a unique component in automotive paint formulation.

Polyvinyl acetate (PVA) is a synthetic resin formlated by the polymerization of vinyl acetate. In its most important application, polyvinyl acetate serves as the film-forming ingredient in water-based (latex) paints; it also is used in adhesives.

Vinyl acetate (CH_2=CHO_2CCH_3) is formulated from ethylene by reaction with oxygen and acetic acid over a palladium catalyst. Under the action of free-radical initiators, vinyl acetate monomers (single-unit molecules) can be linked into long, branched polymers (large, multiple-unit molecules), in which the structure of the vinyl acetate repeating units is:

polyvinyl acetate. Paints are applied for colouring and protecting many surfaces, including houses, cars, road markings and underground storage vessels. Paint is essentially composed of a binder, pigment, and solvent (Allans and Dlant,1984). paint is a liquid - engineered commodity made of several different ingredients that mix to create a specific commodity with unique properties (Rodger, 2008). Bayliss and Deacon, (2002) asserted that paint industry's contribution to the GDP has dropped drastically. This may be attributed to poor government policies on the industry. There is also an astronomical rise in the cost of feedstock for paint making especially polyvinyl acetate due increasing exchange rate, the increase in tariff on imported feestock also play a key role in the increase of paint feedstock. In order to surmount this hurdle it it become necessary to search for local paint materials that will be used as substitute or co-additive for paint production. Research has shown that castor seed oil has similar physiochemical to polyvinyl acetate. Therefore this study is aim to assess the potential of castor seed oil as a substitute or co-additve to polyvinyl acetate for emulsion paint formulation.

MATERIALS AND METHODS

Sample collection

Castor seeds were collected from Orherhe-agbarho, a community in Ughelli North Local Government Area, Delta State.

Castor seed oil, Polyvinyl acetate (binder), water (vehicle), calcium carbonate (extender), ammonia (preservative), texanol (drying agent), genepol (Emulsifier), Nitrosol (Thickener) and calgon (Dispersant) was used for the study.

Extraction of castor seed oil (CSO)

Castor oil seeds were bought from a local market in Agbarho. The castor seed shells were removed from the seed and dried in an oven at 105ºC. The Castor seed oil of 800g was broken down and extracted using soxhlet extraction and petroleum ether as the solvent. The physico-chemical analysis was done on the oil sample to ensure its good in emulsion paint formulation, according ASTM protocol (2010). The oil viscosity was recorded using Ostwald Viscometer at 25ºC using a stopwatch to observe the time of flow resistance of the castor oil. Specific-gravity was analyzed using a specific density bottle of 50ml, the value was obtained using the formula; specific gravity (SG) = volume of oil sample divided by volume of water. The refractive-index was determined using the Abbe-refractometer of AR-200 model, and the boiling point was analyzed using the thermometer of 0-300^{0}C capacity. The drying time of the oil was observed under atmospheric conditions and the time of film formation was recorded after 30minutes (Osemeahon, 2016).

Preparation of Polyvinyl acetate and Castor See Oil (PVA/CSO) Blends and Films

A blend of PVA/CSO was formulated by adding varying amounts of CSO in PVA resin. The mixture was agitated and left for 1 days at room temperature and then poured into a glass Petri dish for casting. The resin was also allowed to cure.

Emulsion paint production design

Table 1: Formulation of paint production

Formulation	Volume of PVA (ml)	Volume of CSO (ml)	Total volume (ml)
1	250 (100%)	-	250
2	-	250 (100%)	250
3	150 (60%)	100 (40%)	250
4	100 (40%)	150 (60%)	250

Table 2: Formulation 1 of emulsion paint production

Additives/ Materials used	Quantities used
PVA(ml)	250
CSO (ml)	-
Nitrosol (g)	50
$CaCO_3$(kg)	1
Deformer (ml)	10
Ammonia (ml)	3
Calgon (ml)	12.5
Texanol (ml)	25
Genepol (ml)	10
Water (ml)	300

Table 3: Formulations of PVA, CSO, PVA and CSO combination of emulsion paint production

Materials/ additives	Formulations			
	1	2	3	4
PVA and CSO blend (ml)	PVA,100	CSO,100	PVA,40/CSO,60	CSO,60/PVA,40
Nitrosol (g)	50	50	50	50
$CaCO_3$ (kg)	1	1	1	1
Water (ml)	300	300	300	300
Deformer (ml)	10	10	10	10
Ammonia (ml)	3	3	3	3
Calgon (ml)	12.5	12.5	12.5	12.5
Taxanol (ml)	25	25	25	25
Genepol (ml)	10	10	10	10

Preparation of emulsion paint

A 300 ml of distilled water (H_2O) was measured with a measuring cylinder at room temperature to be at 0.3L and was poured into the reaction pot. The water serves as a solvent in the reaction.

Calcium carbonate is a whitish substance in a powdery form occurring in nature, it is used in the production of paint to give the paint body (coverage) or hiding capacity. 1kg calcium carbonate was measured in a measuring bowl using weighting balance and was poured into the reaction pot that already contained water and was stirred thoroughly for 5 minute.

Calgon is also a whitish substance in powdery form that looks just like salt and it is used in paint production in order to make the dissolving of calcium carbonate in water faster, this is to eliminate formation of bubble in the paint. The calgon was measured in a measuring bowl using a weighting balance to be 12.5ml and was poured into the reaction pot while the stirring of water and calcium is still ongoing. After adding the measured calgon, the mixture was stirred for 5 minutes.

The Binder which include the varying ratio of castor seed oil and Polyvinyl acetate (CSO/PVA) which was used in a batch is a whitish substance in semi- liquid form and act as a surfactant on the paint. It gives the paint sticking ability to the surface. The higher concentration of PVA presence in paint formation provides more durability of the paint. The CSO/PVA was measured in a bowl using a weighting balance to be 100% PVA, 100% CSO, 60/40 PVA/CSO, and 40/60 PVA/CSO in each batches and was poured into the mixture in the different reaction pots and the mixture in the reaction pot was stirred thoroughly for another 5 minutes. Deformer is a substance in a liquid form and is inevitable. It is used in paint production to subside the foam or bubbles formed when PVA mix was added into the mixture. Formalin is a colourless liquid but has a choky smell, it is used in paint production to preserve the paint for some period of time. Both the formalin and deformer was measured in a measuring bowl using weighting balance at 20 ml and 10 ml respectively and were poured into the mixture and stirred for 5 minutes. Nitrosol is a whitish substance in powdery form that looks just like salt and it is used in paint production to thicken the mixture in the reaction pot. The nitrosol was measured in a measuring bowl to be 50g using the weighting balance; the measured nitrosol was first poured into a conical flask and mixed with 0.20 liters of water. The mixture of nitrosol and water in the conical flask was shaken for 30 seconds and then poured at once into the mixture in the reaction pot and was stirred for 10 minutes to avoid the forming of bubbles. The mixed nitrosol (Thickener) was poured into the reaction pot and was thoroughly mixed with water into the reaction pot. The resultant mixture (forming paint, nitrosol and water) in a vessel was stirred for 10 minutes; the paint was readily produced.

Determination of physiochemical properties of castor seed oil

pH

The pH was determined with Adams pH metre according to ASTM 2010 protocol

Viscosity

The viscosity was analyzed with Oswald viscometer using ASTM, 2010 procedure.

Specific gravity

The specific density was analyzed with 25 ml density bottle using ASTM method.

Refractive index

The refractive index was carried out with an Abbe refractometer as described by ASTM,2010.

Flash point

The flash point was determined with a flash point tester (ASTM, 2010)

Boiling point

The boiling point was determined with boiling point glasswares and 300^{O}C thermometer in accordance with ASTM, 2010 method.

Determination of percentage (%) yield

Percentage (%) yield of oil $=\frac{weight\ of\ oil}{weight\ of\ sample}$ x 100

RESULTS AND DISCUSSIONS

The physico-chemical analysis of castor seed oil is shown in Table 4. The values of the refractive index (RI) and viscosity is within the recommended range of industrial standard for emulsion-paint formulation (Daniel, 2007). The high viscosity is a benefit that control the melt flow of paints. The increase in specific SG of the oil sample could be due to solvent contamination during the extraction process.

Table 4: Physiochemical Properties of Extracted Castor Seed Oil

Appearance	RI	SG (g/cm^3)	Viscosity at 25^{0}C(mPa)	pH	B.P (^{0}C)	F.P
Pale yellow	1.471	2.00	0.425	4.92	330.00	256.00

Determination of percentage (%) yield

The castor seed oil yield was found to be 43.75%, this high yield will be of a greater value for paint making.Physiochemical properties of polyvinyl acetate, castor seed emulsion paint and PVA/CSO combination paint

Table 5: Physiochemical properties of polyvinyl acetate, castor seed emulsion paint and PVA/CSO combination paint

Parameter	Formulation 1	Formulation 2	Formulation 3	Formulation 4
Opacity	10	22	12	9.5
Viscocity at 26^{0}C	0.94	0.94	0.92	0.94
S.G (g/cm^3)	1.01	1.02	1.15	1.12
Drying time (minutes)	25	30	25	25
pH	7.9	8.6	8.0	7.9

The viscosity-value for paint formulation 2 was lower as dipcted in Table 5, because of a high volume of the castor oil, which reduces the cohesion of the intermolecular force along the chains and increases free flow, flexibility, elongation and workability of the paint components. It has been suggested that the drying time of paints can generally be decreased due to the presence of the ricinoleic acid. The stages of drying, from Dust- free time to touch dry, through tack dry and hard dry time (Table 5), displayed adequate results for the research paint as compared with the conventional PVA paints. The castor seed oil paint displayed higher gloss, flexibility, increased adhesion, durability and smooth surface and provided additional protections
to the substrate against corrosion and other weathering conditions, as observed on the coated steel panels.

The emulsion paint produced with Formulations 1, 3 and 4 showed more levelness and gave a deeper coloured paint in all the cases. However, the lower the PVC used the more the compatibility and the deeper the colour obtained. The paints showed good flow property which made them easy to apply and was also found to possess high opacity.

The entire sample paints showed a moderate viscosity which indicated good flow property. Though, emulsion paint formulations 1, and 2 has a high viscosity when compared with Formulation 3 and 4.

Formulation 3 has a higher density of 1.15 kg/l which is higher than formulation1 and formulation 2 with densities of 1.01kg/l and 1.12 kg/l respectively. Formulation 4 has a higher density than formulation 2.

The pH of the paints were also normal (between 7.0 and 9.0) (Table 5) and the pH is in the range of 7.0 - 9.0 which is in conformity with the National Institute of Standard (NIS).

The opacity result on formulation 2 paint produced was higher than that of 1, 3 and 4

CONCLUSION

The results from the study indicate that castor seed oil is adequate for the production of emulsion paint. It also reveals that a combination of castor seed oil and polyvinyl acetate was also effective in the paint production. In the same vein, the combination of 40/60% polyvinyl acetate and castor seed oil was more effective in production due to its low viscosity (0.92^{0}C) and high specific density (1.15 kg/l) .

It is therefore recommended that castor seed oil is a valuable seed that can be used in emulsion paint production. A Combination of 40% castor seed oil and 60% polyvinyl acetate should be used in emulsion paint production.

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