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Epoxidized Palm Kernel Oil and Monomethylol Urea as Co-Polymer Binder for a Water-Resistant Paint

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Abstract

The development of eco-friendly and efficient binders remains a critical focus in modern paint formulation. In this study, the triglyceride structure of palm kernel oil was epoxidized and structurally modified to create reactive sites for chemical bonding. The resulting epoxidized palm kernel oil (EPKO) was chemically blended with monomethylol urea (MMU), a thermoset resin obtained from one-step condensation polymerization of urea and formaldehyde to produce a hybrid copolymer composite (EPKO/MMU). Structural characterization using Fourier Transform Infrared Spectroscopy (FTIR) confirmed chemical interactions between EPKO and MMU, evidenced by upward and downward shifts in absorption bands. Rheological evaluation revealed enhanced film-forming properties. Viscosity, refractive index, elongation at break, and turbidity increased with higher EPKO content up to 50%, after which deviations were observed. Conversely, melting point, density, formaldehyde emission, and moisture uptake decreased with continuous EPKO incorporation. The hybrid copolymer successfully combined the advantages of both components, mitigating the rigidity and high formaldehyde emission of MMU while enhancing flexibility, hydrophobicity, and water resistance contributed by EPKO. The findings demonstrate the potential of EPKO/MMU composites as sustainable, high-performance binders for emulsion paint applications, offering improved environmental compatibility and superior material properties.

Keywords: Monomethylol Urea; Epoxidized Palm Kernel Oil; Hybrid Composite; Copolymer; Emulsion Paint; Water Resistance; Characterization

INTRODUCTION

Paints are complex formulations comprising pigments, solvents, binder and additives. The binder plays a critical role in film formation, pigment dispersion, adhesion to substrates. While traditional synthetic resins like alkyds, acrylics, and polyurethanes are widely used, there is a growing interest in alternative binders derived from low-cost and environmentally benign source (Dweck & Buchler 2005)

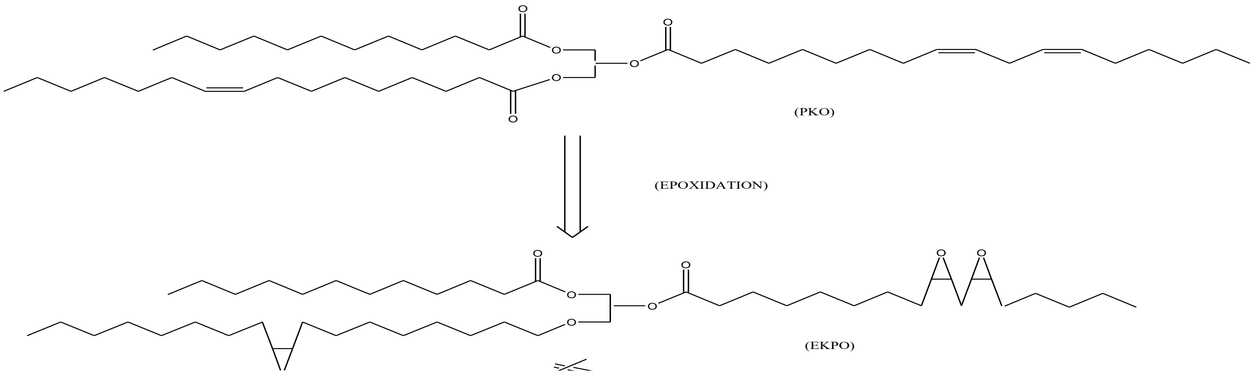
Monomethylol urea (MMU), synthesis via the hydroxymethylation of urea with formaldehye, represents a class of amino resins that exhibit film-forming and cross-linking abilities (jin *etal.*, 2017). However MMU alone may lack sufficient mechanical durability and water resistance for exterior coatings. To enhance its performance, combining MMU with Epoxidized palm kernel oil a flexible water resistant polymer could yield a suitable binder in paint formulation (George & Kurian., 2016).

The ester groups in the glyceryl part and the double bonds in the carboxylic acids chains are most significant and promising. These active sites can be used to usher in reactive groups. Hydroxylation, Epoxidation, esterification of vegetable oils and their derivatives are giving most consideration when it comes to the modification of fatty acid chain (wang *et al.,* 2013). Vegetable oils contain several actives sites that cooperable/acquiescence to chemical modification.

Palm kernel oil has a balanced ratio of unsaturated and saturated fatty acids. It has a stable high cooking temperature (high smoking point), longer shelf life, stay longer than other vegetable oils. Zero cholesterol (even though it is high saturated fat), it is relatively low in cost. Thus, the ester linkage and/or COOH group of the palm kernel oils can undergo such reactions as hydrolysis, esterification, saponification, amidation, halogenation etc, while double bonds undergo reactions such as oxidative polymerization, hydrogenation, epoxidation, halogenations, sulphonation and so on (Bashar and Jumat, 2010).

Epoxidation of oil is a chemical process in which carbon-carbon double bonds (C=C) present in unsaturated fatty acids of oils are converted into epoxidized groups (also called Oxirane) by reacting with oxidizing agents, commonly paracids (like performic acids or paracetic acid)

This study presents the synthesis and Characterization of MMU, its copolymerization with EPKO and the evaluation of the composites as a binder in water-based paint formulations.



Chemical Conversion of Palm kernel oil to Epoxidized palm kernel oil

MATERIALS AND METHODS

Epoxidation Palm Kernel Oil

Epoxidation was carried out using the method describe by Goud *et al.*, (2007). 200cm^3 of oil was introduced in a 1000cm^3 three necked flask equipped with a reflux condenser and a thermocouple. The flask was place on a hot plate with temperature control. Acetic acid and formic acid at a molar ratio of 0.5:1 to the oil and sulphuric acid catalyst 3% weight were added. A hydrogen peroxide as an oxygen carrier of a molar ratio 1.5:1 to the oil was added drop wise into the mixture. The feeding strategy is required in order to avoid overheating the system since epoxidation is an exothermic reaction. The reaction was maintained at uniform state by using a magnetic stirrer which runs at about 1600rpm under isothermal condition at 50-60°C. The product was cooled and decanted in order to separate the organic-soluble compounds (epoxide oil) from water-soluble compounds. Warm water was used to wash the epoxidized oil (in small aliquots) in order to remove residual

Resin Composition

MMU was prepared using the one step process (OSP) as reported by Archibong and Osemeahon (2019) with some modifications. One mole of urea (6.0g) was made to react with one moles of formaldehyde (8.11ml) 37-41% (w/v), using 0.02g of sodium dihydrogen phosphate as catalyst. The pH of the solution was adjusted to 13.0 by using 0.1MH_2SO_4 and 0.5MNaOH solutions. The solution was heated in a thermostatically controlled water bath at 50^0C. The reaction was allowed to proceed for 60min after which the resin was removed and kept at room temperature (30^0C).

Copolymerization

This was carried out by blending different concentrations (10-70%) of EPKO with MMU that is 10ml of MMU was made to react with 60ml 0f EPKO, 20ml of MMU reacts with 50ml of EPKO, 30ml MMU reacts with 40ml of EPKO etc.

Determination of Gel Time

Gel time was determined by gel-time meter. The temperature was set for 121°C in gel time meter and filled with liquid paraffin till the brim of the container. The heating system and stirrer were switched on. 10 gms of the sample was weighed and it was taken in a test tube and placed vertically in hot paraffin bath using wooden holder. Resin level in the tube was taken such that it was well within hot bath. A glass rod was placed in test tube and it was locked to the spindle drive with magnetic couple. The spindle was now rotated. When the top spindle rotates, magnetic coupling and bottom fin also started rotating along with glass rod. When the resin started solidifying, rotation of glass rod was resisted, which in turn stop rotation of bottom fin. Upper fin, still rotating freely, come into contact with static one, and the time was noted from the stopwatch. The gel-time was determined.

Determination of Melting Point

To determine the effect of melting point on monomethylol urea (MMU) and that of the composite, a melting point differential macrophase separation technique was developed. In this technique, MMU was introduced into a porcelain dish. The dish with it content was transferred into an oven set at 120^oC for curing. The mixture was removed periodically from the oven and stirred until the mixture gelled and finally solidified. The temperature was then raised to 150ºC and left for 5min after which the sample was removed and cooled for observation. The experiment was repeated three times.

Determination of Viscosity

Viscosity was determined by adopting Ganeshram *et al.,* 2013 method, using Brookfield viscometer. Spindle number was selected and the speed of motor was set. The temperature of the solution was measured using temperature probe. The spring cap was removed and the spindle was fixed. It was immersed up to the mark in the resin and the motor switched on. Spindle rotates inside the solution and produces shear, which gives value of viscosity. It was carried out at a temperature of 25°C.

Determination of Turbidity

The turbidity of the samples was determined by using Supertek digital turbidity meter (Model 033G). Each sample was subjected to three readings and the average taken

Determination of Density

The density of the resins was determined by taking the weight of a known volume of resin inside a density bottle using Pioneer (Model PA64) weighing balance. Three readings were taken for each sample and average value calculated.

Determination of Refractive Index

The refractive index was measured using Abbe refractometer which measure the extent to which light is bent when it moves from air into the sample. Each sample was subjected to three readings and the average taken.

Determination of Moisture Uptake

The moisture uptake of the resin films was determined gravimetrically, according to method described by Archibong *et al.,* 2018. Known weights of the samples 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 recorded as the moisture uptake by the resin. Triplicate determinations was made for each sample and the average value recorded.

Determination of Elongation at Break

The elongation at break was determined using Inston Tensile Testing Machine (Model 1026). Resin films of dimension 50mm long, 10mm wide and 0.15mm thick was brought to rupture at a clamp rate of 20mm/min and a full load of 20kg. Three runs were carried for each sample and the average elongation evaluated and expressed as the percentage increase in length.

Determination of formaldehyde emission using UV-Spectrophotometer

To determine any possible absorbance by formaldehyde, deionized water was used as the blank. The cuvette was rinsed several times with tap water followed by deionized water, it was then filled with deionized water, and placed in the holder, and the spectrophotometer was blanked at 563 nm. The sample was then put into another cuvette and the absorbance was noted at the same wavelength of 563 nm, with concentration recorded

Determination of Water Solubility

The solubility of MMU was determined by mixing 1ml of the resin with 5ml of distilled water at room temperature (30^0C). The degree of solubility was evaluated visually and the result recorded.

RESULTS AND DISCUSSION

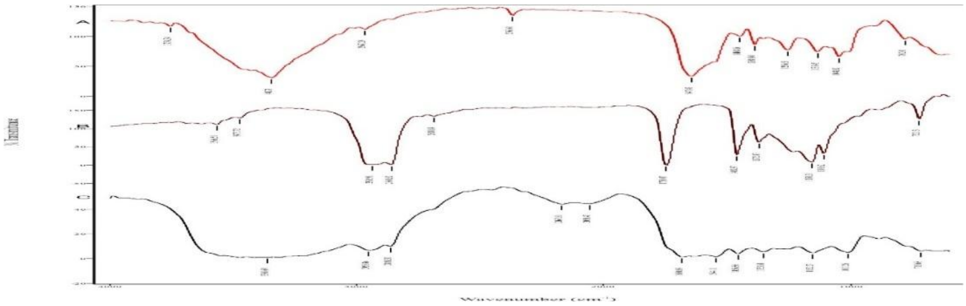


Fig.1 FTIR Spectra of A=MMU, B=EPKO, C=MMU/EPKO

Fig.1 shows the spectra of A (MMU), B (EPKO). C (MMU/EPKO). The FT-IR spectra of A (MMU) shows the appearance of a sharp band in the region 3754.34 cm^{-1} and another broad band at 3344.73cm^{-1} frequency indicating the presence (OH) on the monomethylol urea. The appearance of stretching bands at 2967.29 cm^{-1} and 2369.61 cm^{-1} indicates the presence N-H, the peak at 1647.43 cm^{-1} is due to C=O of urea, the bands at 1448.06 cm^{-1} and 1388.84 cm^{-1} is due to C-H of methylene bridge and the bands at 1256.55 cm^{-1} through 1048.02 cm^{-1} was due to characteristic C-O-C ether linkage stretching (Abbas *et al* 2014).

In the FT-IR spectrum of B (EPKO). The dual band sharp transmitted at 2936.91 cm^{-1} and 2850.82cm^{-1} produced by stretching of the C-H group of alkane in the spectrum of EPKO is easily distinguished. The appearance of oxirane bonds near 834cm^{-1} and 843 cm^{-1}. The peak at 1750.07 cm^{-1} indicates C=O stretching vibrations of the saturated ester present in the oil (Yelwa *et al.,* 2017). The region of 1460.97cm^{-1} and 1372.87 cm^{-1} of the IR spectrum show two bands that correspond to the bending vibration of C-H of alkane. The peak at 1158.31 cm^{-1} is due to C-O stretching mode of carboxylic acid (Patrick et al., 2009).

In the MMU/EPKO spectra the O-H peak at 3754.34cm^{-1} in MMU now appeared a lower frequency band of 3360.69cm^{-1}, this may be due to the hydrogen bonded hydroxyl groups that contribute to the complex vibrational stretches associated with free inter-and intra-molecular bound hydroxyl groups (Shashidhara and Jayaram, 2010). Also the frequency bands of C=O, N-H, CH_2, C=C, C-O-C, C-H in MMU and EPKO all shifted to a different bands in the MMU/EPKO composite, thus indicating chemical reaction actually took place between MMU and EPKO.

Effect of EPKO concentration on the Density of MMU/EPKO

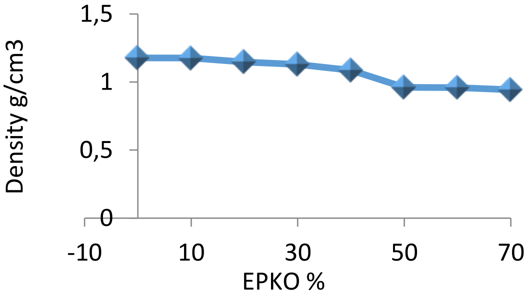


Fig.2 Effect of EPKO concentration on the Density of MMU/EPKO

The density of a paint binder plays crucial roles in determining the performance of the coatings. Density of binders can substantially influence levelling, sag resistance, pigment dispersion, brushability, and flow behavior. Density of binders often improves stabilization and distribution by promoting adsorption and reducing flocculation, which contributes to consistent color and gloss

The effect of EPKO concentration on the density of MMU/EPKO is presented in fig.2. The density decreases with increasing inclusion of EPKO. Physical properties of polymer depend on chain length and content of soft and hard segments. The initial decline could be due to the inherent flexible structure of carboxylic acid chains, which is not susceptible to form compact crosslinked structure compared to the stiffer MMU repeat units (Unar *etal.*, 2010). It can also be the result of differences in the molecular features and morphology which influenced the packing nature of resin molecules as the concentration of EPKO increases. The decrease observed from 0 to 70% EPKO loading could be due to increasing amount of soft segment (Mavani *et al.,* 2007). Unreactive saturated components like cryptic acid and lauric acid pendant chains in EPKO enhance the flexibility and degree of freedom for movements of the molecular chains in the monomethylol urea network and hence a reduction in the degree of crystallinity and molecular weight.

Effect of EPKO concentration on the Refractive index of MMU/EPKO

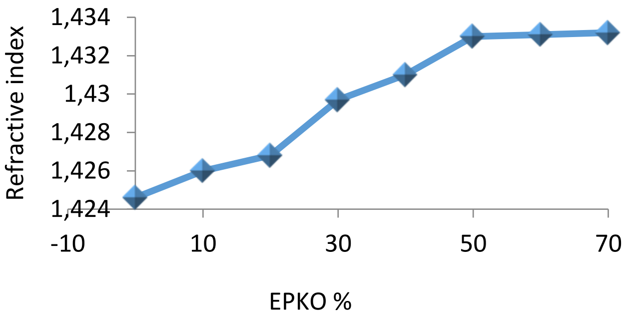


Fig.3 Effect of EPKO concentration on the Refractive index of MMU/EPKO

Gloss refers to the capacity of a coated surface to reflect light, contributing to the visual appearance and aesthestic quality. The reflection of light from the surface can be broadly categories into two components specular and diffuse. Specular reflection involves the direct reflection of light in a single direction, akin to a mirror-like surface. While diffuse reflection occurs when light penetrates the surface, undergoes multiple internal reflections and refractions, and then exit in the surface in various direction (Boussu et al., 2014)

Fig.3 is a plot of the effect of EPKO on the Refractive index of MMU/EPKO. The refractive index increases with increasing EPKO percentage inclusion until it got to a point where the continuous addition appeared to have no effect on the refractive index. It became apparently clear from the results that, as the molecular weight of the polymer increases due to hydrogen bond interactions and the coupling effect of the EPKO it resulted in an increasing crosslinking density, the refractive index increases in value in reflection of the polymer molecular weight increase. By inspection, it is observed that in the low molecular weight region these values show an unmistakable upward trend with increasing molecular weight. The influence of molecular weight on refractive index may entirely be an end group/pendant group effect because as the proportion of repeat units to end groups increases, the refractive index increment approaches higher values (Khot *etal.*, 2001). The point where inclusion of EPKO appeared to be of no effect in the refractive index may be attributed to a possible fall in crosslinking density as the result of polymer degradation with increasing EPKO concentration.

Effect of EPKO concentration on the Gel time of MMU/EPKO

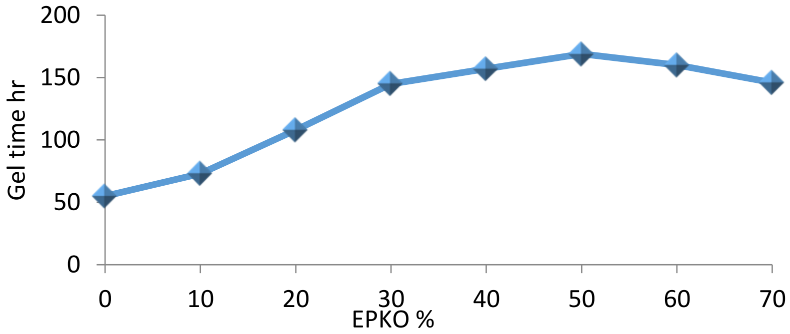


Fig.4 Effect of EPKO concentration on the Gel time of MMU/EPKO

As gelation is approached, viscosity increased dramatically and the molecular weight goes to infinite. The reaction between monomers leads to the formation of network, hence gelation. Both molecular weight and poly-dispersity increase until one single macromolecule is formed. At this point, the behavior of the system changes from liquid-like to rubber-like thus the reactive system becomes a gel (Gonzalez *et al.,* 2012).

Fig.4 shows the graph of EPKO concentration on the gel time of MMU/EPKO. Addition of EPKO results to the gel time rise of MMU/EPKO. This may arise from the fact that the structure of oils contain fatty acids with carbon–carbon double bonds that can act as sites for chemical coupling, which in turn creates a strong polymer cross linkages. This observable pattern could also be explained in terms of increase in molecular weight and cross-linking density which culminated to increase in viscosity and high viscosity results to increase gel time (Menkiti and Onukwli, 2011). After 50% addition phase inversion and dissociation might have sets in and this explains the slight decrease in the gel time.

Effect of EPKO concentration on the Melting point of MMU/EPKO

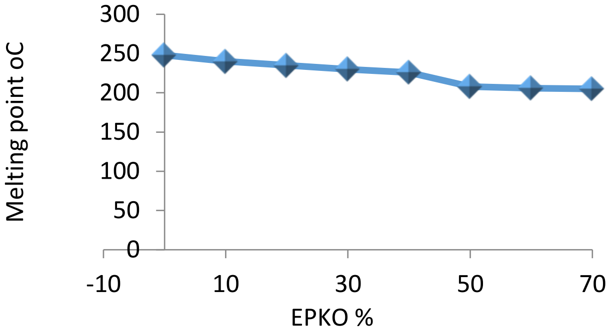


Fig.5 Effect of EPKO concentration on the Melting point of MMU/EPKO

Thermal property, molecular weight, degree of cross linking and the level of rigidity of the polymer is related to its melting point. The melting point of a compound increases with its molar mass, intermolecular Van der Waals interactions and also the intrinsic structures that affect the rigidity. In the case of coating industry, the melting point of a binder is related to its thermal resistance as well as to the brittlity.

Fig 5 The graph of the effect of EPKO concentration on the melting point of MMU/EPKO. The melting point decline as the EPKO concentration increases. The decline in melting point of the compound indicates domination of plasticising action of vegetable oil over its coupling effect, hence a decline in melting point (Qi et al., 2002). It is also seen that up to a certain concentration of EPKO in the composite, melting point shows an increasing trend, the increase in the melting point of the composite might be a manifestation of increasing cross-link density, thus, confirming the findings by Kukreja *etal.* (2002) that vegetable oil acts as a coupling agent causing increase in cross-link density and it also involves in the physicochemical bonding with the MMU interfaces.

Effect of EPKO concentration on the Viscosity of MMU/EPKO

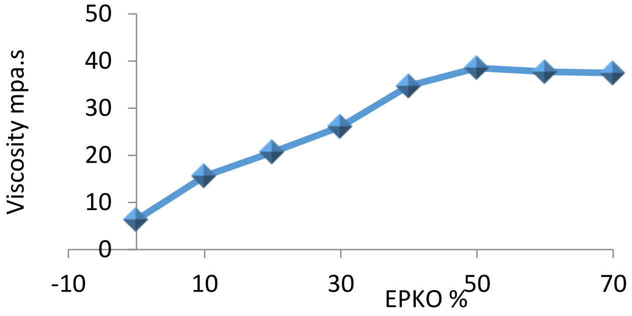


Fig.6 Effect of EPKO concentration on the Viscosity of MMU/EPKO

Viscosity of the binder controls many of the processing and application characteristics such as flow rates, leveling and sagging, thermal and mechanical properties, dry rate of paint film and adhesion of the coating to the substrate their importance cannot be down played (Archibong and Osemeahon, 2019).

Fig. 6 represent the plot of the effect of EPKO concentration on the viscosity of MMU/EPKO. The viscosity increases with increased percentage addition of EPKO, but at above 50% inclusion of EPKO, the viscosity then decreases. The probable reason for the increased viscosity could be a reflection of incremental intermolecular interactions between the MMU monomer and the palm kernel oil carboxylic acids, for they are made of groups that can instigate the creation of large amount of hydrogen bonds between hydroxyl and ester group. Destruction of these hydrogen bonds and their entanglement at higher EPKO concentration may have been the reason for the decline observed at above 50% inclusion (Archibong *etal.*, 2024). This apparent increase in the viscosity may also have been contributed by the formation of higher crosslinking density of the polymeric matrix due to increasing curing of MMU and EPKO.

Effect of EPKO concentration on the Turbidity of MMU/EPKO

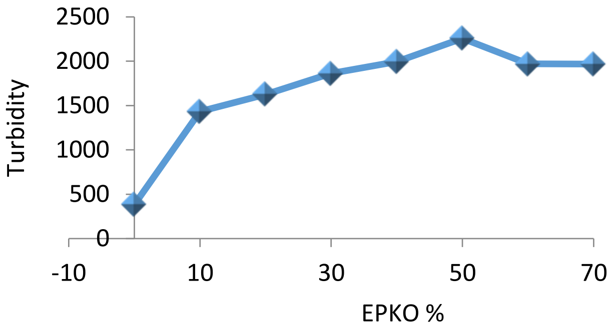


Fig.7 Effect of EPKO concentration on the Turbidity of MMU/EPKO

When we have homogeneity and few particles, there is usually less light scattering; hence, higher scattering is observed when we have a non-homogenous system with a lot of particles. Turbidity of the binder is usually performed in order to characterize the optical properties of the binder as related to gloss property. The refractive index gives an indication of the turbidity. Light interaction with a colloidal system is its turbidity. Turbidity of the system can be used as an indication of the level of interchain cross-linking (Al-Marnasir, 2009).

Fig 7. Shows the graph of the effect of EPKO concentration on the turbidity of MMU/EPKO. The turbidity of MMU is seen to rise at the onset with increasing EPKO concentration and at about 50% EPKO inclusion it starts to decline. The increase could be the result of growth of large polymer aggregates due to several inter-polymer interactions occurring fast as a result of the availability of bonding sites, and tendency towards sedimentation with EPKO increases (Sahad, 2015). The polymer chains might have experience a strong frustration in chain packing in the interfacial region due to the formation of large loops at high EPKO addition and inability of the longest chains to be incorporated in the crystalline structure, resulting in the decreasing turbidity (Bin *et al.*, 2016).

Effect of EPKO concentration on the Elongation at break of MMU/EPKO

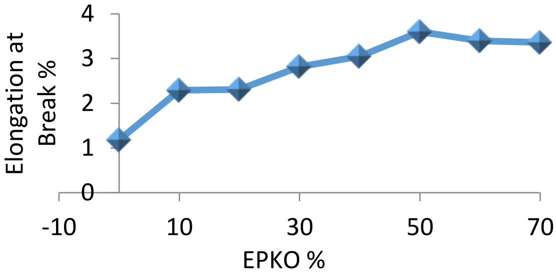


Fig.8 Effect of EPKO concentration on the Elongation at break of MMU/EPKO

Elongation gives a picture of how much the material will withstand stretch before breaking. The rigid nature of thermosetting resins creates mechanical and structural limitations for wide applications. Elongation at break can be a tool to determine the adhesion between phases, because of its sensitivity for load transfer between phases (Cakir *et al.,* 2012).

The plot of the effect of concentration of EPKO on the elongation at break of MMU/EPKO is shown in fig.8. The elongation rises steadily with increasing EPKO inclusion. Research has shown that plasticizers lower tensile strength of film but increase percentage elongation as depicted above where the incorporation of EPKO brings about the depressions of tensile strengths due to the plasticizing effects and thus increases the elongation at break (Madufor *etal.,* 2013). Elongation at break measures the ductility of the material. In as much as a high concentration of EPKO could often permits fast crosslinking process in the composite, this could also bring about the formation structural defects in the composite network such as dangling chains that are not elastic active, this could perhaps attempt to explain the reason for the decline noticed above 50% EPKO addition. Also the increase in elongation at break could be due to increase in molecular mobility emanating from the specific interactions between MMU and the flexible hydroxylated palm kernel oil. The decrease in cross-link density induces increase in elongation at break with increase in EPKO content not beyond 50%, for beyond this value polymer degradation must have set in.

Effect of EPKO concentration on the Formaldehyde emission of MMU/EPKO

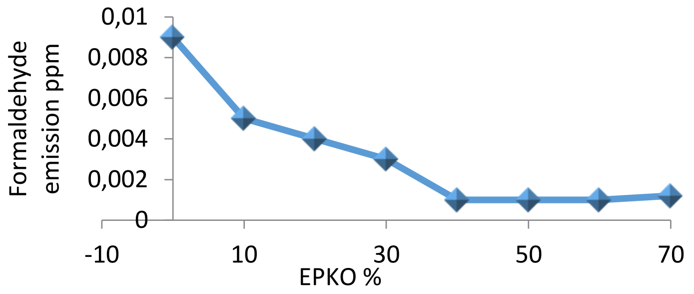


Fig.9 Effect of EPKO concentration on the Formaldehyde emission of MMU/EPKO

Fig. 9 depicts the graph of the effect of EPKO concentration on the formaldehyde emission of MMU/EPKO. Hydrolysis of cured urea resins has been known to be responsible for formaldehyde emission leading to sick building syndrome (Park *et al.*, 2010). High emissions of formaldehyde from latex paint have been reported by Salthalmmer *et al.* (2010). The formaldehyde emission shows decreasing tendency with increasing concentration of EPKO concentration, which was very obvious at 40% content. This could possibly be due to the deceleration of curing process which influence change of methylene-ether bridges and various active sites in triglyceride structures like the double bond, the ester group, the allylic carbons, and the carbons α to the ester group, consequently, the decreasing of methylene-ether bridges causes the reduction of formaldehyde emission (Garnier, 2002). It could also be due to the reduction in stress during cure which reduces emission as a result of improve flexibility brought about by the introduction of EPKO to MMU, since a reduce density results in high flexibility and increased ability to absorbed but less ability dissipate energy (Stefana *etal.,* 2005).

Because of the health implications of formaldehyde emission on humans and its environs, it is a matter of survival to determine it emission during MMU synthesis and application. The present result shows that formaldehyde emission is even below the acceptable level of (0.10ppm).

Effect of EPKO concentration on the Moisture uptake of MMU/EPKO

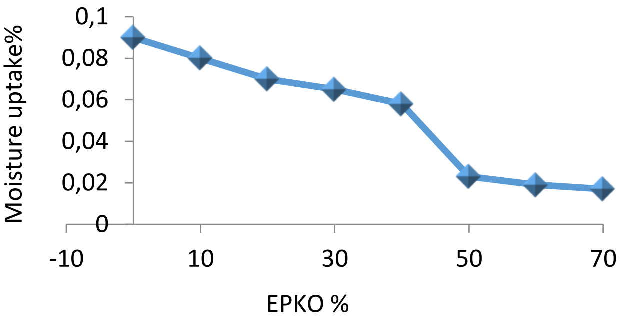


Fig.10 Effect of EPKO concentration on the Moisture uptake of MMU/EPKO

Waterborne coatings are susceptible to durability issues pertaining poor water resistance. 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 (Emile, 2003; Bharath and Swamy, 2009).

The graph of the effect of percentage concentration of EPKO on the moisture uptake of MMU/EPKO is shown on fig.10 above. There is a gradual lowering of the moisture uptake decline with gradual addition of EPKO. MMU polymers are by nature highly hydrophilic, but when EPKO are typically included, they introduced hydrophobicity to the polymer matrices, hence boosting reinforcement and matrix adhesion and thus decreases it hydrophilicity.

Therefore, the decline could be credited to the increasing quantity of soft/flexible and hydrophobic hydroxylated palm kernel oil component to fade off the rigid and compact nature of MMU polymer, as well as implanting a water proof resistance of EPKO to the composite. Increasing interactions of EPKO with MMU due to availability of enough hydrogen boning sites could also leads to a lower composite swelling ratio, which is an indication of not only high crosslinking density but also a lower absorbability of the network in the solvent in this case water (Unar *etal.*, 2010). The low moisture uptake recorded in the MMU/EPKO composites could also be explained in terms of the reduction of MMU loading in the presence of the hydrophobic palm kernel oil.

Table 1. Effect of EPKO concentration on the solubility in water of MMU/EPKO resin

EPKO concentration (%)	Solubility
0	Soluble
10	Soluble
20	Soluble
30	Soluble
40	Soluble
50	Soluble
60	Insoluble
70	Insoluble

The effect EPKO concentration on the solubility in water of MMU/EPKO copolymer is presented in table1. As seen from the table (0-50)% EPKO concentration, the composite is soluble in water because the hydrophilic nature of MMU dominates, at this point the copolymer is in a hydrophilic state, with MMU having higher influence. This allows it to stay in aqueous solution, but when EPKO concentration starts increasing it leads to the formation of globule-like conformation that most often becomes insoluble in water (Unar *etal.*, 2010). Also, the effect of interchain repulsions due to increasing EPKO inclusion may allow hydrophobes to take part at least to some extent in intramolecular associations.

Table 2: Comparison of some Physical Properties of MMU/HPKO Film with Films from other Paints Binders

Type of resin	Physical property							
	Viscosity (mpa.s)	**Refractive Index**	**Density (g/cm^3)**	**Melting point (^{0}C)**	**Moisture uptake (%)**	**Elongation at break (%)**	**Formaldehyde emission (ppm)**	**Literature**
MMU/EPKO	**38.5**	**1.4331**	**0.96113**	**1208**	**0.023**	**0.23**	**0.02**	**This present work**
Acrylic/Methyl crilic ester	2500	ND	1.03	ND	ND	ND	ND	Kirana *et al* (2018)
Polyvinyl butyral	9-16	1.485	ND	ND	0.3	110	ND	Donnchadh *et al* (2008)
MU/NR	248	1.3411	0.641	255	1.341	350.43	0.058	Kazys and Rekuviene (2011)

Type of resin	Physical property							
Innovative UF	365	ND	ND	ND	0.25	ND	0.07	Zorba *et al* (2008)
TMU/EPS	19.70	1.425	1.0990	262	1.01	425	0.0233	Osemeahon and Dimas (2013)
Commercial UF	451	ND	1278	ND	2	ND	ND	Suupere *et al* (2006)
UF/PE	32.60	1.432	1.3362	130	0.0080	250.0	0.0142	Osemeahon and Archibong (2011)
Palmoil/Alkyd	499	ND	0.929	ND	ND	ND	ND	Blaise *et al* (2012)

CONCLUSION

Modification of monomethylol urea with various percentage of epoxidized palm kernel oil was experimentally successful, their structural and mechanical properties were analyzed. Other parameters, looked at were the possibilities of using these modified monomethylol urea and its composite resins as a paint binder, comparable to the conventional binders which we hope to published on the next edition.

All examined monomethylol urea blends presented a better rheological and film-forming properties compared to the pure thermosetting resin. At 50% content, the blends presented a more magnified properties in viscosity, gel time, moisture uptake, elongation at break, refractive index and melting point etc. thus, providing an overall improvement on the monomethylol resin setbacks. The amplification of rheological, mechanical and film-forming properties of the modified monomethylol urea resins led to a dramatic increase in their paint binder 's values. These noticeable advantages seen in this work will be very germane for future projection and the applications of the paint binders taking into account the relative low cost and availability of the epoxidized palm kernel oil added and the simplecity in the whole manufacturing process.

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