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Synthesis of fast drying long oil alkyd resins using seed oil of Karawila (*Momordica charantia*)

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Seed oil of the agricultural variety, *Momordica charantia* (MC43) cultivated in Sri Lanka, has been used to synthesize long oil length (65%) air drying alkyd resins by monoglyceride process. Esterification reactions were continued until the resins were about to gel. Final acid values are found to be close to 10 mg g^{-1} with high extent of polymerization values, mostly above 0.95. Alkyd resins of Seed Oil of MC43 are found to have fast drying characteristic, mainly due to the presence of 56.59% of eleostearic acid. Unlike for tung oil (80% of eleostearic acid), the risk of gelation for seed oil of MC43 is found to be less significant. Glycerol improves the extent of polymerization but imparted poor film properties. Good film properties have been achieved with a minimum molar ratio, 0.45, of pentaerythritol to seed oil of MC43.

Keywords: Karawila seed oil, Long oil alkyds, *Momordica charantia*

Alkyd resins are popular in surface coating industry due to their cost effectiveness, versatility, and availability of basic raw materials. Manufacturing process has been well established over the years and many new sources of fatty oils were introduced in recent past. Even if the basic raw materials are the same, new improved formulations are continuously developed in order to be competitive in the paint industry. Quality requirement for numerous applications such as architectural paints, wood finishers, metal finishers, and road marking paints is determined by the combination of film properties; level of film hardness, drying behaviour, water resistance, chemical resistance and glossy. In most of the conventional oil modified alkyd formulations, glycerol and phthalic anhydride react with fatty oil to form polymer back-bone. Pentaerythritol is used as an alternative to glycerol in long oil length alkyd formulations to impart high viscosity, fast-drying, greater hardness, better gloss, gloss retention and superior water resistance[1].

Seed oil having considerable amount of unsaturated fatty acids such as soya bean oil, dehydrated castor oil, linseed oil and tung oil are common sources for alkyd industry. In addition to these conventional oils, tobacco seed oil[2],nahar seed oil[3], rubber seed oil[4], African locus bean seed oil[5], Egyptian apricot oil[6], deodorizer distillate as a by-product from vegetable oil refineries[7] are also identified as suitable sources for making alkyd resins. Some work has further been reported on attempts to change the structure of alkyd molecules and to change the structural properties of cross-linked network in dried films for developing desired film properties[8-15].

MC43 is an agricultural variety of Karawila (*Momordica charantia),* commonly known as bitter gourd, available in Sri Lanka. Seed oil of MC43 (SOMC43) is a good drying oil[16]. It is having a moderate Iodine value of 115.96 cg/g is comparable to other common fatty oils available in alkyd industry (Table 1). Iodine value of soya bean oil is 146.37 cg/g but soya bean oil was unable to form a dried film even after 24 h as compared to 2 h of set-to-touch drying time for SOMC43[20]. Similarly, iodine value of tung oil is considerably less than that of linseed oil but tung oil has better drying characteristics. Further it has the ability to form a rigid film having higher resistance against water penetration and saponification[22]. This is mainly attributed to the presence of 56.59% and 82.00% of conjugated octadecatrienoic acid (eleostearic acid) in SOMC43 and tung oil respectively (Table 2). Saponification value and acid value of SOMC43 are comparable to linssed oil, soya bean oil and tung oil but are considerably low with compared to rubber seed oil and tobacco seed oil. High acid values are not

Table 1 — Comparison of fatty oil properties

Fatty oil	Saponification values (mg/g)	Acid value (mg KOH/g)	Iodine value (cg I_2/g)	Specific gravity
Rubber seed oil [17]	206.20	53.09	135.36	0.910
Linseed oil [18]	176.00	4.37	188.00	0.931 - 0.936
Tobacco seed oil [19]	212.06	26.37	161.94	0.908 - 0.917
Soya bean oil [20]	185.36	1.05	146.37	0.908
Tung oil [21]	189-185	8.00	163.00	0.935-0.938
SOMC43 [16]	190.70	2.73	115.96	0.930

Table 2 — Comparison of fatty oil composition

Fatty oil	Oleic acid % (18:1)	Linoleic acid % (18:2)	Linolenic acid % (18:3)	Eleostearic acid % (18:3)	Stearic acid % (18:0)	Pamitic acid % (16:0)
Rubber seed oil [24]	24.60	39.60	16.30	-	8.70	10.20
Linseed oil [25]	18.51	17.25	53.23	-	4.43	6.58
Tobacco seed oil [26]	34.00	8.90	0.40	-	8.00	28.9 (16:0) 16.7 (16:1)
Soya bean oil [27]	22.75	54.45	6.90	-	4.60	11.20
Tung oil [21]	4.00	8.50	-	82.00		5.50
SOMC43 [16]	1.98	3.70	-	56.59	35.08	2.15

desirable for the activity of basic catalyst used in alcoholysis process[23]. Hence alkali refining or esterification of free fatty acids is required for such fatty oils before the monoglyceride process. On the other hand, fatty oils with low acid values such as SOMC43 can be directly used to prepare alkyd resins using monoglyceride process.

The relative amounts of monoenoic acid (oleic acid) in rubber seed oil, tobacco seed oil and soya bean oil are comparable but tobacco seed oil contains notably less amount of dienoic and trienoic acid (linoleic and linolenic acid) and hence it shows poor drying characteristic. Even though soya bean oil contains high amount of dienoic and trienoic acid (61.3%), drying rate of soya bean oil is three times slower than the linseed oil under same conditions. But the high degree of unsaturation of linseed oil with high amount of trienoic acid (53.23% of linolenic acid) may result in auto oxidation and polymerization to form cross-linked tough film upon expose to air[22]. Trienoic acid in tung oil (eleostearic acid) contains conjugated triene system with compared to methylene interrupted triene system in linolenic acid. Consequently tung oil has better drying characteristic over linseed oil. However, tung oil is unable to use alone as a source for manufacturing alkyd resins due to high risk of gelation resulting from thermal polymerization of eleostearic acid moities via Diels Alder addition reaction at processing temperatures of 200-240°C. Therefore tung oil is always blended with a semidrying fatty oil to overcome the gelling effect. Similar to tung oil SOMC43 also contains eleostearic acid but with a moderate amount. In a previous work by the same authors, SOMC43 was blended with soya bean oil and the drying characteristics of the alkyd resins were found to improve notably[20]. The objective of the present study is to examine the suitability of SOMC43 for synthesizing long oil length alkyd resins without blending any other fatty oils and to evaluate the factors that affect film properties and risk of gelation.

Experimental Section

Materials

Oil was extracted from the dry seeds of MC43 available in Sri Lanka by the method of solvent extraction[28-30] using *n*-hexane as the solvent. Pentaerythritol (Sigma-Aldrich), phthalic anhydride, (Sigma-Aldrich), sodium methoxide (Fluka chemicals), glycerol, toluene, and isopropyl alcohol (Merck chemicals) were all of analytical grade. An alkyd resin sample from Lankem Ceylon Limited, Sri Lanka, was used as a reference to evaluate the film properties. This alkyd was based on soya bean oil having oil length of 55% and acid value of 10 mg g^{-1}. Viscosity(c-poise at 25°C) for 55% solid was given as 5000.

Experimental work

Experimental work was divided into two phases; preparation of air drying alkyd resins (oil length 65%) from SOMC43 and evaluation of film properties. Monoglyceride process was carried out for synthesising the alkyd as SOMC43 had a low acid value. Subsequently polyesterification was done by using solvent process in order to minimize the loss of phthalic anhydride by sublimation. Five necks polymerization flask equipped with mechanical stirrer, Dean and Stark apparatus, thermometer and nitrogen inlet were used. The mixture was purged with nitrogen to repel air to prevent oxidation during reaction. Reaction of SOMC43, glycerol and pentaerythritol with 0.2% (w/w to the fatty oil) sodium methoxide as catalyst was carried out while stirring at 1650 ± 10 rpm and maintaining at a fixed temperature of 240°C. A sample of 1 mL was taken out for methanol tolerance test, 10 min after reaching the temperature of 240°C. Thereafter samples of 1 mL were tested for methanol tolerance in intervals of 5 min. The conversion process of SOMC43 to monoglyceride was continued until it forms a homogeneous solution when mixed with methanol[31,32]. The reaction mixture was cooled to 180°C at the end point of the methanol tolerance test.

Xylene was used as the solvent with an amount of 6% of the initial weight of polyesterification mixture. The required amount of xylene and phthalic anhydride were added to the monoglyceride mixture at 180°C and temperature of reaction medium was gradually increased to 200°C. Bubbling of N_2 gas and stirring of reaction medium were continued at constant rates throughout the polyesterification. Reaction medium was maintained at 200°C until fluidity of the mixture became significantly low (close to gel point). The stirrer speed was found to drop sharply at this point. Then the reaction was stopped before gelation by allowing the reactor to cool suddenly in blowing air. Samples of about 5 g were taken out at 15 min intervals during the polyesterification and also after the reaction medium and cooled to room temperature, for analyzing the acid value.

Several combinations of reagents were selected to prepare alkyd resins in order to compare the film properties. Stoichiometry of the reaction between glycerol and fatty oil for monoglyceride process is 2:1. Amount of excess OH groups was calculated based on the stoichiometric amount of OH groups. Oil length of the alkyd resin was kept constant at 65% by varying the amount of phthalic anhydride. Group 1 experiments (denoted as G') were performed using glycerol as the only polyol and the excess OH percentage was varied from 2.5 to 12.5%. In the next set of experiments, pentaerythritol was also used as an additional source to supply the stoichiometric amounts of OH in combination with glycerol. The amount of pentaerythritol was gradually increased within a group while glycerol amount was decreased correspondingly. In groups 2, 3 and 4 (denoted as G), glycerol was used to supply the excess OH while pentaerythritol was used for groups 5 and 6 (denoted as P) for the same purpose. Table 3 summarizes these experiments with the amount of excess OH percentage, final acid value (AV_f) when the fluidity of the mixture became significantly low (close to gel point) and the extent of polymerization (P). Molar ratios of glycerol (a), pentaerythritol (b) and phthalic anhydride (c) to SOMC43 under each group are also given.

Testing of film properties

Solid content (non-volatile matter) of resultant alkyd resin samples and reference sample was adjusted to 70% by adding turpentine to examine the film properties. Cobalt napthenate (6% of Co^{2+} in mineral spirit) and Lead stearate (24% of Pb^{2+} in mineral spirit) were used as drying agents with elemental compositions of 0.05% and 0.5% respectively, with respect to the total solid content of alkyd resin solution. Alkyd resin solutions were then applied using 50 micron applicator bar on glass panels [ASTM D1640-69] for evaluating drying characteristics, steel panels of thickness 1 mm [ASTM D609-73] for evaluating hardness and adhesion, and thin steel panels of thickness 0.25 mm [ASTM D609-73] for evaluating flexibility. Set to touch drying time (ASTM D640-69), hardness after 48 h (ASTM 3363-92a), adhesion to the metal substrate (ASTM D3359-92a), flexibility (ASTM D522-92) and water resistance (ASTM D1647-89) were also evaluated. The reference alkyd resin sample from Lankem Ceylon Limited, Sri Lanka, was used to compare with the film properties of selected recipes.

Calculation of number average degree of polymerization

Synthesis of alkyds follows step growth polymerization between dicarboxylic and mixture of polyols having hydroxyl functionality 2 or above and the repeating unit consists of two structural units, one of each from dicarboxylic acid and polyols. In the present study hydroxyl functionality of 2 (monoglyceride), 3 (glycerol) and 4 (pentaerythritol) were used to react with phthalic anhydride.

Acid value is used as end-group analysis to calculate the number of molecules present at any moment of polymerization. The calculation is based on set of assumptions; each molecule contain –COOH group at one end of molecule, molecules do not contain either –COOH or –OH groups at both ends, side reactions (eg: etherification, dimerization) do not occur and no cyclic molecules are formed during the polymerization.

Extent of polymerization is defined as the fraction of the functional group that has reacted. Acid value at zero reaction time (AV_o) and acid value at any moment of polymerization (AV_t) can be used to calculate the extent of polymerization at any moment[33]. Extent of polymerization (p) at the end of polyesterification can be calculated using initial acid value and final acid value (AV_f) as given in Eq 1.

$$p = \frac{AV_o - AV_f}{AV_o} \quad \text{... (1)}$$

Since the stoichiometry of the reaction between –COOH and –OH to form ester bond is 1:1, the moles of ester bonds formed per unit mass (n_{EB}) during the polyesterification can be calculated using Eq 2.

$$n_{EB} = \frac{AV_o - AV_f}{56100} \quad \text{... (2)}$$

Equations (1) and (2) can be combined to calculate the number of ester bonds per unit mass (n_{EB}).

$$n_{EB} = \frac{AV_f}{56100}\left[\left(\frac{1}{1-P}\right) - 1\right] \quad \text{... (3)}$$

The number-average degree of polymerization is defined as the ratio of the initial number of molecules (N_o) to the number of molecules (N_t) at any moment of polymerization or else using initial number of moles (n_o) and the number of moles (n_t) at any moment of polymerization. Therefore number average degree of polymerization at the end (X) can be calculated as a ratio of initial moles of molecules (n_o) present at zero reaction time to moles of molecules present at the end of polymerization (n_f).

$$X = \frac{n_o}{n_f} \quad \text{... (4)}$$

Table 3 — Molar ratios of reagents and results of polyesterification

Group number	Experiment number	$\frac{n_{glycerol}}{n_{SOMC43}}$	$\frac{n_{pentaerythritol}}{n_{SOMC43}}$	$\frac{n_{phthalicanhydride}}{n_{SOMC43}}$	Excess OH %	AV_f mg g^{-1}	P
1	G'2.5_1	2.05	-	2.21	2.5	20.4	0.88
	G'8_2	2.16	-	2.16	8	10.96	0.94
	G'10.5_3	2.21	-	2.36	10.5	8.4	0.95
	G'12.5_4	2.25	-	2.03	12.5	4.2	0.97
2	G8_1	1.75	0.20	2.20	8	2.5	0.986
	G8_2	1.54	0.30	2.24	8	5.7	0.968
	G8_3	1.34	0.40	2.28	8	11.2	0.939
	G8_4	1.24	0.45	2.30	8	16.3	0.912
3	G10_1	1.99	0.10	2.13	10	0.99	0.996
	G10_2	1.79	0.20	2.17	10	5.96	0.966
	G10_3	1.58	0.30	2.21	10	6.16	0.965
	G10_4	1.37	0.40	2.25	10	11.65	0.936
	G10_5	1.25	0.46	2.28	10	16.43	0.910
4	G12_1	1.82	0.20	2.14	12	3.47	0.980
	G12_2	1.62	0.30	2.18	12	4.70	0.973
	G12_3	1.41	0.40	2.23	12	10.9	0.939
	G12_4	1.28	0.46	2.25	12	10.3	0.943
5	P10_1	1.60	0.34	2.15	10	5.00	0.97
	P10_2	1.40	0.44	2.20	10	9.28	0.95
	P10_3	1.20	0.53	2.24	10	10.70	0.94
	P10_4	1.08	0.59	2.26	10	9.93	0.95
6	P12_1	1.60	0.37	2.13	12	5.21	0.97
	P12_2	1.40	0.46	2.17	12	8.84	0.95
	P12_3	1.29	0.51	2.19	12	11.93	0.94
	P12_4	1.15	0.58	2.22	12	12.05	0.94

AV_f = Final acid value; p = Extent of polymerization, However, the moles of molecules present at the end of polyesterification is equal to the difference between the moles of molecules present at zero reaction time and moles of ester bonds formed at the end of polymerization (n_{EB}).

$$n_f = n_o - n_{EB} \qquad \text{... (5)}$$

Equation (6) can be derived from Eqs (3), (4) and (5) to calculate the number average degree of polymerization.

$$X = \frac{n_o}{\left[n_o - \frac{AV_f}{56100}\left(\frac{1}{1-P} - 1 \right) \right]} \qquad \text{... (6)}$$

The value of n_o will be equal to theoretical value based on the moles of fatty oil, dicarboxylic acid and polyols available at the beginning of reaction only if fatty oil is completely converted to monoglycerides. However, the degree of conversion of fatty oil to monoglyceride in monoglyceride process depends on type of oil, type of catalyst and temperature[23,34,35]. On the other hand monoglyceride amount can be experimentally determined using periodic acid method[36]. Monoglyceride process mainly form α-monoglycerides over β-monoglycerides due to greater reactivity of α-position and periodic method detect the alpha-monoglyceride[34,36]. The α- and β- monoglycerides exist in an equilibrium mixture containing about 90-92 percent of α-isomer and 10-8 percent β-isomer[37].

In the present study, n_o was calculated using periodic method with the assumption that 10 percent of β- monoglyceridesare present in the mixture.

Results and Discussion

Results of Group 1 experiments given in Table 3 indicate that when glycerol was used as the only polyol, extent of polymerization had increased with the increase in excess percentage of OH groups. This may be attributed to the differences in reactivity of hydroxyl groups present in glycerol. Glycerol has two primary hydroxyl groups and a secondary hydroxyl group. When excess percentage of OH groups is low, all three hydroxyl groups in glycerol may take part in the reaction and form a branched polymer structure. However, as the excess percentage of OH groups increases, probability of phthalic anhydride to react with primary hydroxyl groups in glycerol increases. This may result in high extent of polymerization due to formation of linear polymer structures. Consequently the risk of gelation is reduced.

Results of the next set of experiments indicate that extent of polymerization decreases with the increase of pentaerythritol while excess percentage of OH groups was kept constant within a group. Pentaerythritol has four primary hydroxyl groups that are equally reactive and hence increase of pentaerythritol increases the probability of generating branches. Further, an additional amount of phthalic anhydride was required for maintaining the oil length at 65%. Consequently, formation of a highly branched network structure would be promoted resulting in high risk of gelation as indicated by high acid values and low extent of polymerization close to gel point.

The degree of polymerization (X) significantly increases with decrease in molar ratio of total polyol (including glycerol from oil) to phthalic anhydride (D). This is an indication of forming large molecules at low D and small molecules at high D. In all of these experiments, polyesterification was continued until near gel point was reached and hence molecules in resultant alkyds can be assumed to have branched molecules. Presence of higher amount of polyols with respect to phthalic anhydride may limit the growth of alkyd molecules and hence a large number of highly branched small molecules are formed. On the other hand, presence of relatively less amount of polyols as compared to phthalic anhydride may increase the formation of highly branched large molecules.

The results of set to touch drying time (STDT) of wet films of alkyd resin solutions, shown in Fig. 1, suggest that alkyd resins of SOMC43 generally show fast drying characteristics. Figure 2 shows the variation of pencil hardness of dried films after 48 h from the application of wet films. Group 1 which was having glycerol as the only polyol showed very poor hardness as compared to other groups where pentaerythritol was also present. Pentaerythritol generates four branches in a tetrahedral geometry as

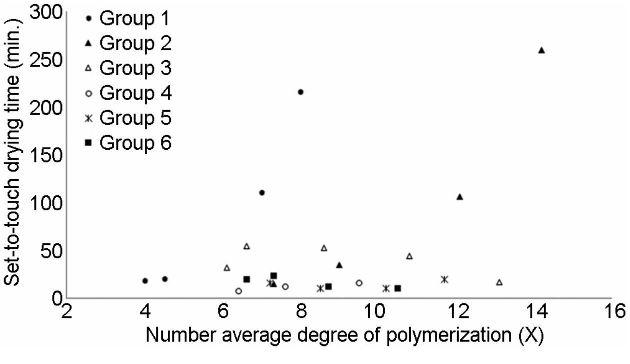

Fig. 1 — Set-to-touch drying time against number average degree of polymerization

compared to three branches formed by glycerol. As a result, presence of pentaerythritol promotes the development of rigid and firm network structures which impart improved hardness properties. Further, hardness was found to increase with the increase in degree of polymerization as indicated in Fig. 2. This result suggests that the average size of molecules is a decisive factor on the hardness of alkyd reins.

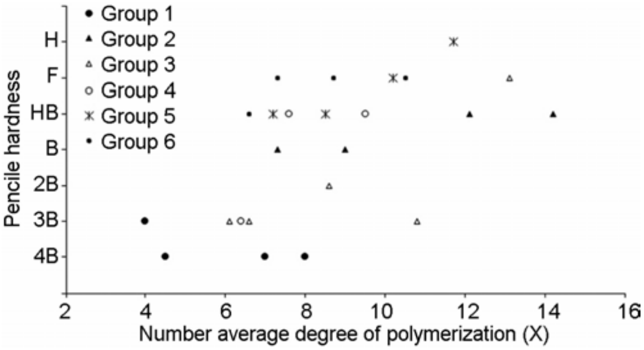

Fig. 2 — Pencil hardness of dry film after 48 h from the application of wet film.

FTIR spectrum of alkyd resin has number of additional peaks as compared to FTIR spectrum of SOMC43. The broad band at 3488 cm^{-1} in spectrum of alkyd resin is due to stretching vibration of unesterified O-H bonds in polyol. A weak peak appeared around 3018 cm^{-1} in both spectra is due to the stretching vibration of=C-H bonds in aliphatic system and the additional peak at 3065 cm^{-1} in the spectrum of alkyd resin is due to vibration of C-H bond in the aromatic ring. A doublet having a strong band at 986 cm^{-1} and a weaker band at 962 cm^{-1} is observed in the FTIR spectrum of SOMC43. They are corresponding to *trans:trans* and *cis:trans* conjugated double bonds in the α-Eleostearic acid[38]. The same doublet is also observed in FTIR spectrum of alkyd resin.

The alkyd formulations tested in present study were divided into three categories (Table 4) by comparing film properties against the reference sample. Category A imparted good scratch hardness (F or above) after 48 h and also gave lowest set to

Table 4 — Film Properties of alkyds resins prepared from SOMC43

Exp. No	Hardness 48h	STDT (min)	Water Resistant (min)	Bend test	Clarity	Adhesion	OH/COOH	$\frac{n_{glycerol}}{n_{SOMC43}}$	$\frac{n_{pentaerythritol}}{n_{SOMC43}}$	$\frac{n_{phthalicanhydride}}{n_{SOMC43}}$
RF	HB	25	50	pass	WC	5B	-	-	-	
Category A										
P10_4	H	20	NVA	pass	WC	5B	1.24	1.08	0.59	2.26
G10_5	F	17	10	pass	WC	5B	1.23	1.25	0.46	2.28
P 10_3	F	10	NVA	pass	WC	5B	1.28	1.20	0.53	2.24
P12_4	F	10	NVA	pass	WC	5B	1.30	1.15	0.58	2.22
P12_3	F	12	NVA	pass	WC	5B	1.35	1.29	0.51	2.19
P12_2	F	23	NVA	pass	WC	5B	1.39	1.40	0.46	2.17
Category B										
G8_4	HB	260	NVA	pass	WC	5B	1.20	1.24	0.45	2.30
G8_3	HB	106	NVA	pass	WC	5B	1.23	1.34	0.40	2.28
G12_3	HB	16	35	pass	WC	5B	1.31	1.41	0.40	2.23
P10_2_	HB	10	NVA	pass	WC	5B	1.35	1.40	0.44	2.20
P10_1	HB	16	NVA	pass	WC	5B	1.43	1.60	0.34	2.15
P12_1	HB	20	NVA	pass	WC	5B	1.47	1.60	0.37	2.13
Category C										
G10_4	3B	44	7	pass	WC	5B	1.27	1.37	0.40	2.25
G8_2	B	35	NVA	pass	WC	5B	1.30	1.54	0.30	2.24
G10_3	2B	53	20	pass	WC	3B	1.34	1.58	0.30	2.21
G12_2	B	12	35	pass	WC	5B	1.39	1.62	0.30	2.18
G8_1	B	15	20	pass	WC	5B	1.38	1.75	0.20	2.20
G10_2	3B	54	20	pass	WC	3B	1.42	1.79	0.20	2.17
G12_1	3B	7	35	pass	WC	5B	1.46	1.82	0.20	2.14
G10_1	3B	32	20	pass	WC	4B	1.50	1.60	0.34	2.15
G’$_{2.5}$_1	4B	215	35	pass	WC	-	1.39	2.05	-	2.21
G’$_{8}$_2	4B	110	40	pass	WC	-	1.50	2.16	-	2.16
G’$_{10.5}$_3	4B	20	15	pass	WC	-	1.40	2.21	-	2.36
G’$_{12.5}$_4	3B	18	20	pass	WC	-	1.66	2.25	-	2.03

NVA = Not visibly affected

touch drying times with excellent water resistance. Category B showed satisfactory level of scratch hardness (HB) after 48 h with excellent water resistance, except for G12_3. Set to touch drying time of Category B was comparable to Category A except for G8_4 and G8_3. Category C showed poor scratch hardness and comparatively low water resistance. A wide range of set to touch drying time was observed for Category C. Results of bend test, clarity and adhesion were satisfactory for all the groups.

Highly improved film hardness of alkyd resins in category A as compared to reference is an indication of forming rigid network structures. These rigid network structures act as good barriers for penetrating water molecules through the surface of dried films resulting in superior water resistance property. This is further confirmed in the results of category C where poor hardness properties and relatively less water resistance properties were observed. According to Table 4, molar ratio of pentaerythritol to SOMC43 in category A is significantly high as compared to that in category C. This suggests that high proportion of pentaerythritol is required to form rigid network structures of alkyd resins of SOMC43. Results in Table 4 depicts alimitation for producing fast drying alkyd resins with film properties acceptable to the industry based on a minimum molar ratio ofpentaerythritol to SOMC43 which is above 0.35. Further, good film properties can be obtained when the ratio of pentaerythritol to SOMC43 is above 0.45. Other properties such as water resistance, bend test, clarity and adhesion of the alkyds of SOMC43 were comparable to the industrial reference.

Conclusion

Seed oil of MC43 is found to be a good source for synthesizing fast drying long oil (oil length 65%) alkyd resins. The fast drying characteristic is mainly due to the conjugated triene system available in seed oil of MC43. Unlike for tung oil (α-Eleostearic acid 80%) the risk of gelation is not significant for SOMC43 (α-Eleostearic acid 50%). Extent of polymerization is found to increase with the increase of glycerol content but decrease with the increase of pentaerythritol content. On the other hand both drying characteristics and film properties could be significantly improved with the increase of pentaerythritol content. The minimum molar ratio of pentaerythritol to SOMC43 for synthesizing fast drying long oil alkyd resins with good film properties is found to be 0.45. Further, number average degree of polymerization is found to decrease significantly with the increase in the ratio of total polyol to phthalic anhydride.

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