Indian Journal of Chemical Technology
Vol. 33, May 2026, pp. 382-390
DOI: 10.56042/ijct.v33i3.23811

Utilizing degraded oils for eco-friendly epoxy films

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Received 15 September 2025; accepted 20 January 2026

With increasing emphasis on waste valorization and sustainable materials, this study investigates the development and characterization of their films derived from epoxidized oils synthesized by discarded blended vegetable oils. These blends of rice bran oil, sunflower and groundnut oil in varying ratios 60:20:20, 50:25:25, and 40:30:30 is subjected to repeated deep frying at 180°C. Discarded oils obtained after frying, first characterized for physicochemical degradation which included viscosity, free fatty acid, specific gravity changes. Then the oils made epoxidized and the resulting epoxidized oils were used to fabricate thin films, which were evaluated for their mechanical properties such as thickness, hardness, flexibility, and adhesion and chemical properties such as epoxy value, acid, alkali resistance etc. The study establishes a sustainable approach to convert discarded oils blends into valuable bio resins with desirable film properties. This finding supports the potential for reusing discarded oils as a low cost, eco-friendly for coating application and contributes to environmental sustainability goals.

Keywords: Bio-resins, Epoxidized oils, Film Properties, Sustainable Coatings, Waste Valorization

Introduction

In recent years, there has been a growing global interest in developing sustainable, bio-based alternatives to conventional petroleum derived materials, in the field of coatings and polymeric films. Among various renewable resources, vegetable oils have emerged as promising feed stocks for polymer synthesis due to their biodegradability, non-toxicity, low cost and reactive functional groups such as double bonds, and carboxylic acids. The chemical modification of vegetable oil by epoxidation and converted into epoxidized resin, which is suitable for applications such as surface coatings and adhesives. Recent advances in epoxy coating technology highlight the potential of integrating both nanotechnology and bio-based materials to enhance coating performance. However, large volumes of used or discarded oils from domestic and industrial deep-frying processes are often improperly disposed of, leading to environmental pollution.

Vegetable oils which consist of triglycerides, i.e., ester of glycerol and three fatty acids, mainly unsaturated[1-3] are also an interesting raw material[4-6] undergo thermal oxidation, hydrolysis and polymerization during frying changes their physicochemical properties. Despite degradation, these oils retain unsaturated bonds which can be chemically epoxidized. Utilizing such discarded oils as raw materials for synthesizing epoxy resins not only addresses waste management challenges but also offers a sustainable route to value added products. In this study, discarded blended oils of rice bran oil, sunflower and groundnut oil in ratio 60:20:20, 50:25:25 and 40:30:30 was collected after deep frying. These oils were characterized for changes in viscosity, acid value, free fatty acid content and specific gravity. The oils were then epoxidized with the help of hydrogen peroxide and formic acid and the resulting epoxidized oils used to develop thin film by curing with ethylene diamine.

Experimental Section

Materials

All the chemicals of Analytical Research (AR) grade were used during experiments and procured from Merck Pvt. Ltd, Mumbai, Maharashtra. Discarded blended oils were collected after 16 h deep frying at 180°C.

Methods

Epoxidation of discarded oils

For epoxidation, discarded blended vegetable oils composed of rice bran oil (RBO), sunflower oil (SFO), and groundnut oil (GO) in varying ratios of 60:20:20 (RSG_1), 50:25:25 (RSG_2), and 40:30:30 (RSG_3) was used. It is a chemical process where carbon double bonds in unsaturated fatty acids of discarded oil are converted into epoxy ring, which is

done using hydrogen peroxide and formic acid. The peracid is formed during reaction of hydrogen peroxide and formic acid which reacts with double bonds in the oil forming epoxidized oil.

Characterization of epoxidized oil

Above synthesized epoxidized oils i.e. $ERSG_1$, $ERSG_2$, and $ERSG_3$ were characterized for their various physical and chemical properties. The incorporation of epoxy group was confirmed by Fourier Transform Infrared Spectroscopy (FTIR), which is a powerful analytical technique[7] used to identify the chemical structure and functional group in the pure RBO, SFO, GO, the discarded oil after deep frying and epoxidized oil**.**

Formation of coating from epoxidized oils

It is achieved through a curing process in which epoxy groups of triglycerides undergo crosslinking with hardeners. This crosslinking process results in the development of a continuous, coherent, and adherent film. To produce coatings, the epoxidized oils were cross linked using ethylene diamine as a hardener in the presence of ethanol as a solvent. Specifically, 10.0 g of epoxidized oil was mixed with 1.2 g of ethylene diamine and 2.0 mL of ethanol. The curing process enabled the epoxy groups in the triglycerides to form a three-dimensional cross linked network, resulting in continuous and adherent films.

Evaluation of film properties

The acid, alkali, solvent resistance and mechanical properties of cured epoxidized oils-based films were evaluated.

Film properties of epoxidized oil

The efficacy of epoxidized oil depends on their physical, chemical, mechanical and thermal characteristics. These properties play major role for the suitability for various applications such as protective coating, packaging and adhesives. The films were prepared by curing epoxidized oils derived from blended discarded vegetable oils at 60°C. The properties of coatings such as thickness, scratch hardness, impact resistance, water absorption, appearance, gloss, flexibility, adhesion, color, water resistance were evaluated using standardized techniques.

Appearance

The appearance of film is characterized by its visual and physical surface characteristic[8]. The cured film appears translucent with pale yellow hue. The surface texture was smooth with a semi glossy hue with no visible cracks or air bubbles.

Film thickness

Film thickness influences the mechanical strength, flexibility and overall performance of film. The thickness was measured by a digital micrometer screw gauge[9]. Thin film samples cast on flat nonstick surface Teflon® and cured at 60°C for 10 h. After complete curing the films were peeled off and film thickness measured at N=5 randomly selected locations. The average value was taken as the final thickness.

Hardness

Hardness is a mechanical property, influenced by the crosslinking, density, epoxy value, curing temperature and composition of oil. Hardness of the cured thin film was determined by using a Shore D durometer with ASTMD 2240 standard[10]. The durometer indenter was applied perpendicular to the film surface and reading was recorded after 1 second of contact. Measurement was taken at three different locations, and the average of three values was noted.

Adhesion

Adhesion is a mechanical property of a thin film that captures the substrates ability to stick to a surface. Cross Hatch Adhesion Test[11] is a simple method used to evaluate the adhesion strength of cured thin film. To measure the adhesion property of a cured thin film on a clean glass plate, 6 to 11 parallel cuts were made through the film using a sharp blade, spaced 2 mm apart. The sample was then rotated by 90°, and a second set of cuts was made perpendicular to the first to form a cross-hatch (grid) pattern. A strip of standard adhesive tape (as specified in standards such as ASTMD 3359) was firmly applied over the cut area and smoothened down to ensure good contact. After waiting for about one minute, the tape was peeled off quickly at a 180° angle. The grid area was then examined to assess how much of the film was removed, and the result was compared to a standard adhesion rating scale such as 5B (no removal, best adhesion) to 0B (greater than 65% removal, poor adhesion) to determine the adhesion quality of the film.

Flexibility

Film flexibility is another mechanical property assessed by the flexural modulus and yield point. It is

the ability of a cured thin film to bend, fold or stretch without cracking. Cured thin film sample, Mandrel bend[12] tester (ASTMD522) is used to measure flexibility. In this method, the film coated panel was warped around a series of rods of decreasing diameter. The smallest diameter at which the film does not crack was recorded.

Impact resistance

Impact resistance is the ability of a cured epoxy resin film to resist sudden force without cracking. It indicates that coating can absorb and disperse mechanical energy caused by impacts. Epoxidized oils, derived from blended used oils, provided good impact resistance, ensuring that the film remained intact under rough handling or external force. To measure impact resistance, the epoxidized oil was applied on a clean metal panel and allowed to cure completely for 7 days at room temperature. The coated panel was then placed on the impact tester. A known weight (1 kg) was dropped from varying heights, and the panel was observed for any signs of cracks, peeling, or delamination. The maximum energy that the coating could withstand without damage was recorded as the impact resistance. This property was measured[13] according to ISO 6272 and expressed in cm kg.

Water, acid, alkali and solvent resistance

For these assessments, the three edges of the film containing glass panels, subjected to immersion were sealed[14] with molten wax (melting point 80°C). The panels were then immersed in 250 mL beaker half filled with water, 5% HCI (W/V) and 5% NaOH (W/V) for 6 days at room temperature, i.e., 27-30°C. The panels were examined at an interval of 24 h for 6 days after washing and drying against the change in characteristics like color, gloss, blisters and wrinkling etc. After 6 days, panels were removed from the beakers and washed with water. Finally, the panels were kept in air for 2 h and examined for any change in characteristics like colour, gloss, blisters and wrinkling etc.

For solvent resistance test, the three edges of the film containing glass panels were sealed with molten wax as the solvents may penetrate through the side of the films. The panels were then immersed for specified period in the beakers half filled with solvents to which the resistance is to be seen. In the present work, solvent resistance test was conducted on the cured films containing panel for 6 days immersion in mineral turpentine oil (MTO), butanol and toluene at room temperature, i.e., 27-30°C.

Results and Discussion

Discarded blended vegetable oils consisting of rice bran oil (RBO), sunflower oil (SFO), and groundnut oil (GO) in three different ratios 60:20:20 (RSG1), 50:25:25 (RSG2), and 40:30:30 (RSG3) were subjected to epoxidation after being repeatedly used for 16 h deep frying at 180°C. Epoxidation was carried out using hydrogen peroxide and formic acid, leading to the formation of peracid, which reacted with the carbon-carbon double bonds present in the unsaturated fatty acids, converting them into epoxy rings. The epoxidized oils (ERSG1, ERSG2, and ERSG3) were characterized for their physical and chemical properties, (Table 1) confirming successful incorporation of epoxy groups. FTIR provides evidences of the successful epoxidation of double bonds (C=C) into epoxy groups (oxirane rings). The FTIR spectrum of the epoxidized resin showed significant changes compared to the spectrum of the non-epoxidized oil indicating the formation of epoxy rings. The epoxidation of discarded oils was confirmed by changes in physical and chemical properties (Table 1) and FTIR analysis (Figs 1-5). The appearance of characteristic epoxy peaks around

Table 1 — Physico-chemical properties of epoxidized oil

Property	ERSG1	ERSG2	ERSG3
Colour	Yellow	Light brown	Brown
Appearance	Clear & Transparent	Clear & Transparent	Clear & Transparent
Specific gravity	0.937	0.933	0.923
Viscosity (cp at 25°C)	208	228	248
Acid value (mg KOH/g)	0.184	0.156	0.134
Iodine value (g I_2/100 g)	52	48	39
Peroxide value (meq O_2/kg)	19.5	17.8	15.8
Saponification value (mg KOH/g)	172.88	168.53	166.43
Epoxy value (%)	5.8	6.3	6.9
Epoxy equivalent (g/eq)	197	189	175

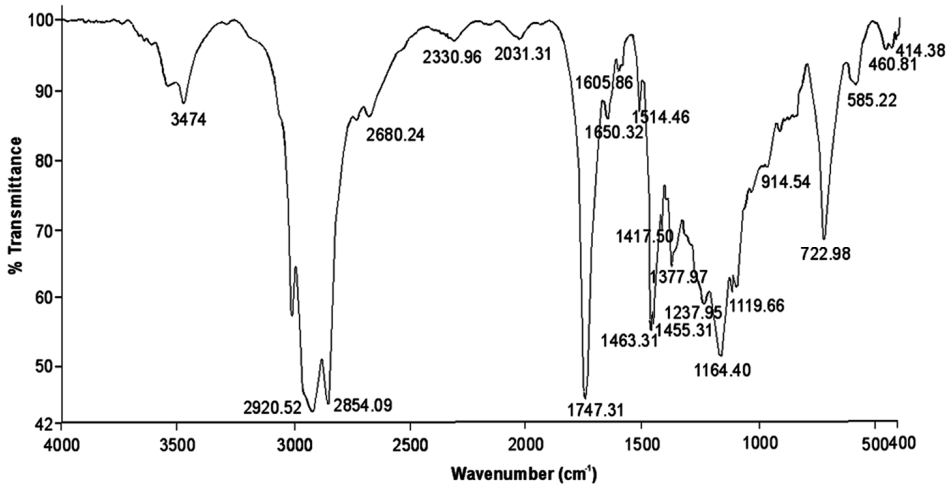

Fig. 1 — FTIR spectrum of rice bran oil

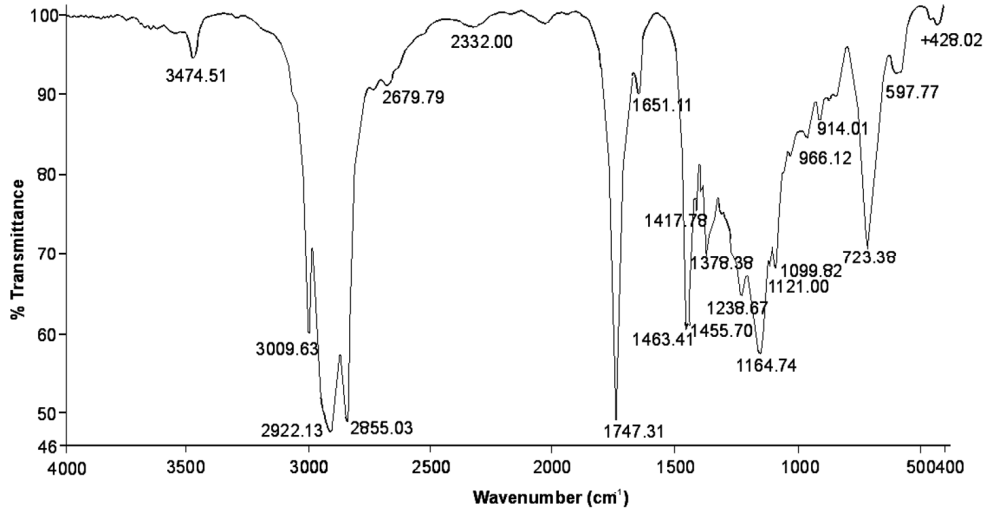

Fig. 2 — FTIR spectrum of sunflower oil

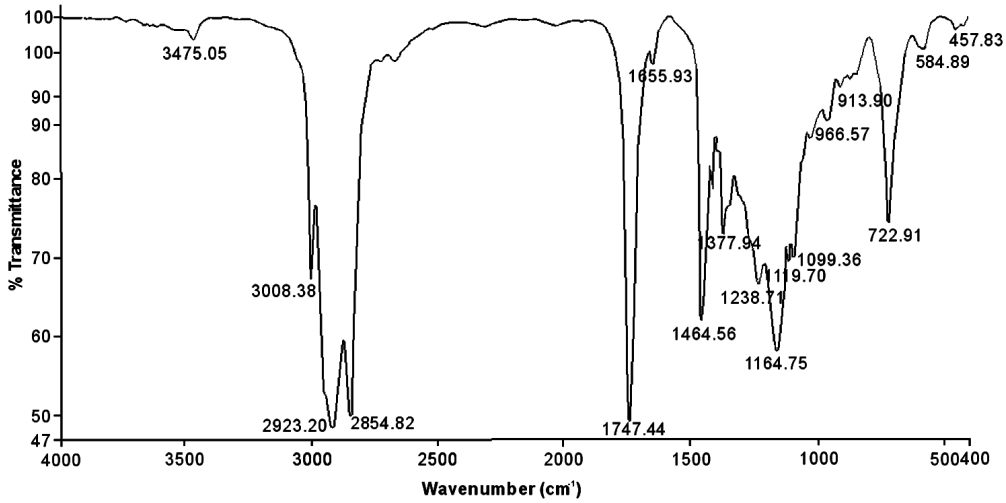

Fig. 3 — FTIR spectrum of groundnut oil

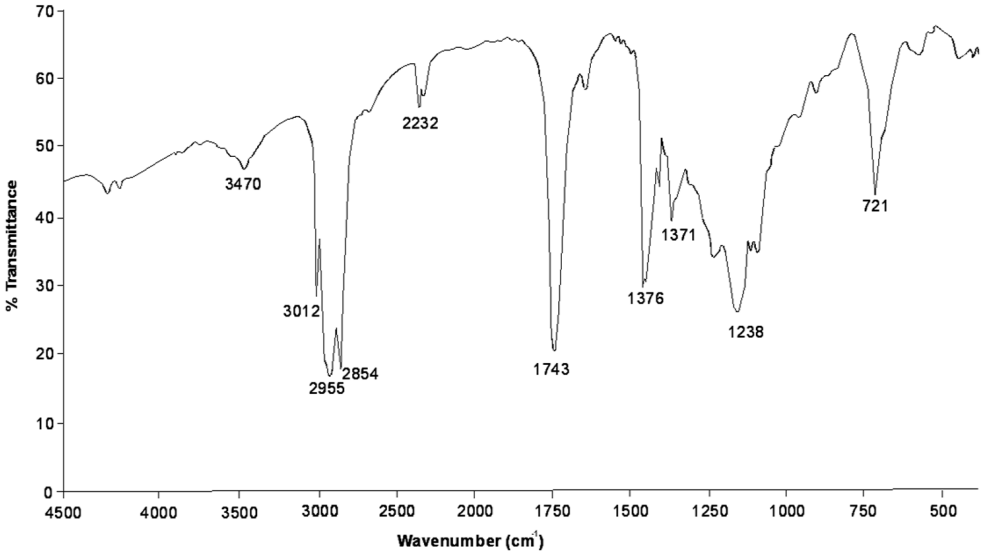

Fig. 4 — FTIR spectrum of discarded oil

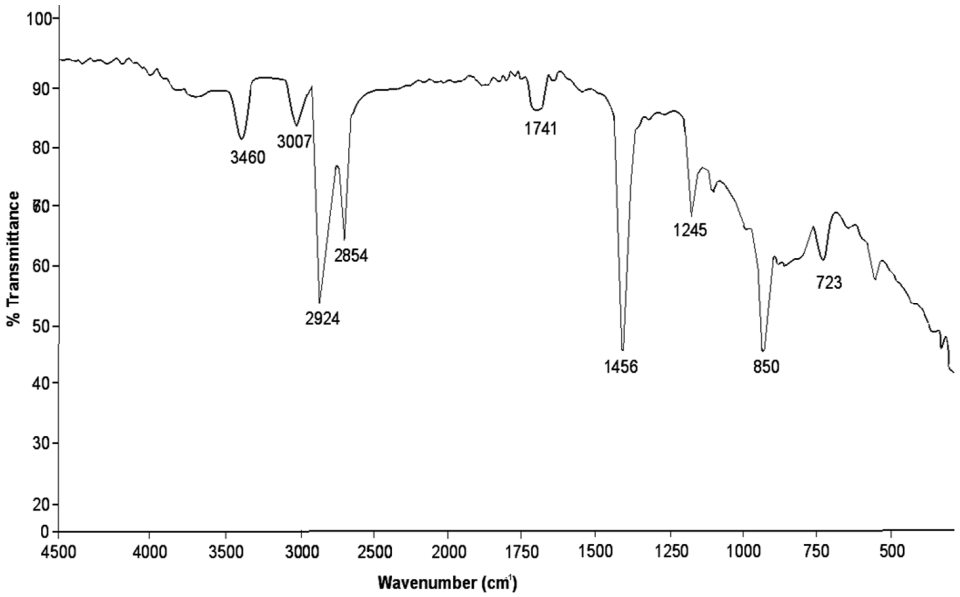

Fig. 5 — FTIR spectrum of epoxidized oil

820–850 cm^{-1} and the reduction of C=C stretching peaks at 1650-1600 cm^{-1} indicated successful conversion of double bonds into epoxy rings. The major peaks observed in the FTIR spectra are shown in the Tables 2-4. Increased viscosity and oxygen content further supported the formation of epoxidized oil. These modifications enhance the oil's reactivity and suitability for use in coatings and resins. The results demonstrate the potential of converting waste oils into valuable, eco-friendly materials, contributing to sustainability and waste reduction in industrial applications.

To prepare films, the epoxidized oils were crosslinked using ethylene diamine as a hardener in the presence of ethanol as a solvent. The resulting coatings were evaluated for their appearance, distilled water, acid, alkali, solvent, mineral turpentine oil resistance, along with mechanical properties. The cured films demonstrated good resistance to water, oil, and various solvents. The coatings exhibited uniform thickness, good hardness, and strong adhesion, indicating their suitability for applications in protective coatings, packaging materials, and adhesives. The thermal curing at 60°C further

Table 2 — FTIR spectral peaks assignments of pure RBO, SFO, GO oils

Wavenumber (cm^{-1})	Assignment	Intensity		
		RBO	SFO	GO
3470-3450	O-H Stretch broad	Very weak	Very weak	Very weak
3008	=C-H(cis-alkene)	Moderate	Strong	Weak
2924–2854	CH_2/CH_3 stretching (aliphatic)	Strong	Strong	Strong
1747	C=O stretching(ester)	Very strong	Very strong	Very strong
1650-1655	C=C stretching	Moderate	Stronger	Weak
1465	CH_2 bending	Present	Present	Present
1377	CH_3 symmetric	Present	Present	Present
1237-1160	C-O/C-O-C stretching (ester)	Multiple peak	Multiple peak	Multiple peak
721	CH_2 Rocking	Present	Present	Present

Table 3 — FTIR spectral peaks assignments of discarded oils

Wave number (cm^{-1})	Band	Assignment
3470 (Broad)	Increased broad O-H absorption	Alcohols, carboxylic acid, Hydroperoxides, moistures uptake indicating, oxidation and hydrolysis
3012	=C-H(cis) decrease	Loss of cis C=C (unsaturation due to oxidation /epoxidation/isomerization)
2955-2854	CH_2/CH_3 stretching	Largely retained but may show intensity changes
1743	C=O stretching	Original triglyceride ester bond shift due to formation of oxidized carbonyl
1654	C=C stretching	Loss of double bonds
1238	C-O (ester linkage)	Formation of secondary products
721	=C-H (out of plane)	Lower intensity confirmed reduction in unsaturation

Table 4 — FTIR spectral peaks assignments of epoxidized oil

Wavenumber (cm^{-1})	Band	Assignment
3460	O-H stretching	Ring opening (hydrolysis occurs during and after curing)
3007	=C-H stretching (cis double bonds)	Disappearance shows reduction of unsaturated bonds during epoxidation
2924-2854	Asymmetric and symmetric C-H stretching	Characteristic of long chain methylene ($-CH_2-$) from fatty acid
1741	C=O stretching	Triglyceride ester linkage
1650	C=C stretching vibration	Reduction in intensity confirms conversion of double bonds
1456	CH_2/CH_3 bending vibration	Aliphatic chain
1245	C-O-C stretching	Confirms presence of epoxy groups
850	C=O stretching (ring deformation epoxy group)	Strong new band confirms epoxidation
723	$(CH_2)n$ rocking vibration	Retention of triglycerides backbone after epoxidation

contributed to improved film integrity and performance.

The epoxy value of the epoxidized discarded oil blend followed the order ERSG1 < ERSG2 < ERSG3. The blend ERSG1 showed the highest epoxy value, indicating the high unsaturation level of RBO before epoxidation the greater number of double bonds allowed a greater degree of epoxidation resulting in more oxirane groups. Upon curing, these groups formed a dense, rigid cross linked network, which makes ERSG1 is superior chemical and water resistance but lower impact resistance. ERSG2 exhibit a moderate epoxy value and having intermediate composition and have substantial number of oxirane groups and higher proportion of SFO and GO reduced the total unsaturation level hence lowering the crosslink density compared to ERSG1. ERSG3 has lowest epoxy value, the high proportion of SFO and GO reduced the number of double bonds for epoxidation which results into the fewer oxirane groups and a lower crosslink density in the cured film.

Physico-chemical properties of epoxidized oil

The change in colour from sample ERSG1 yellow to ERSG3 brown (Table 1) may be due to oxidation during the epoxidation process. All the samples remain clear and transparent shows that all the suspended particles were removed. As the degree of epoxidation increases, noticeable trends emerge in physical and chemical properties. Due to the reduction in unsaturation the specific gravity shows a slight decrease from sample ERSG1 to ERSG3. On the other hand, sample ERSG3 has the highest viscosity due to the incorporation of epoxy group which contribute the molecular rigidity and stronger intermolecular interactions. The acid value decreases from the samples

ERSG1 to ERSG3, shows the consumption of free fatty acids during the reaction which makes ERSG3 more suitable for industrial use. A decreasing trend in the iodine value confirms the conversion of double bonds into epoxy groups. The peroxide value is lowest in ERSG3, confirming better oxidative stability. The epoxy content directly shows the efficiency of epoxidation ERSG3 has the highest epoxy content.

Appearance of epoxidized oil based films

The colour of the coating changed from pale yellow to dark amber (Table 5). This variation is due to degree of thermal oxidation of the oil during deep frying. The ERSG1 have yellow colour due to high RBO content and higher natural pigments concentration. The coatings from ERSG2 have dark yellow and balanced pigment level from blend oils. The change in colour of coatings from light to dark followed the following sequence ERSG1 < ERSG2< ERSG3. The light colour of film has higher gloss because they reflect more light. As the colour darken the gloss of film reduces due to absorption of more light and reflection of light is decreases and film becomes less glossy.

Sample ERSG1 exhibit the lowest transparency as the higher RBO content, antioxidant γ-oryzanol and tocopherols and other pigments that absorb visible light. The higher chromophore density reduced light transmission. ERSG2 have moderate transparency with balanced pigments concentration and better light transmission compared to RBO rich blend. The coatings formed from ERSG3 have highest transparency due to less pigments and smoother polymer. ERSG2 shows good uniformity and smooth surface, ERSG1 and ERSG3 have moderate uniformity but smooth finishes may be due to higher consistency and surface quality.

Thickness

The thickness of coatings derived from epoxidized resins depends upon the oil blends compositions. The measured thickness for the films prepared from ERSG1, ERSG2 and ERSG3 were 73 µm, 70 µm and 65 µm, respectively (Table 6). This gradual decrease in film thickness is related to the proportional of SFO and GO in oil blend composition and the resin cross linking density. RBO contains higher saponification matter and greater amounts of oryzanol and sterols compared to SFO and GO. These anti-oxidant contributed to a higher viscosity and better resin formation in ERSG1 blend forming slightly thicker films. The increased viscosity may result in a slower flow during casting .On the other hand, increasing SFO and GO content diluted the oryzanol rich fraction reducing the film build and leading to thinner layers. Furthermore, the differences in the fatty acid composition among the three oils may influence the epoxidation and resins curing. RBO is richer in unsaturated fatty acids such as oleic acid and linoleic acid which are more reactive during epoxidation and crosslinking and form thicker film, thickness is an important factor affecting various coatings properties such as mechanical strength, water resistance, flexibility and adhesion .Therefore across different oil blends could potentially influenced the overall coating performance.

Hardness

The hardness of a coating film (Table 6) indicates its resistance to deformation, scratching which is essential for protective applications. In this study, the pencil hardness test was used to evaluate the surface hardness of the thin films prepared from epoxidized resins derived from discarded blended oils Among the tested samples, thin film derived from ERSG1 oil blend exhibited the highest hardness 2H pencil grade without damage, while the film from ERSG3 showed lowest hardness HB. This variation could be attributed to differences in cross linking density and fatty acid composition.The result showed that the film

Table 5 — Appearance of epoxidized oil based films

Sample code	Colour	Gloss	Surface texture	Transparency	Uniformity
ERSG1	Light yellow	Highest gloss	Smooth	Semi transparent	Moderate
ERSG2	Pale golden brown	High gloss	Slightly rough	Moderate transparent	Good
ERSG3	Dark amber	Moderate gloss	Slightly uneven	Transparent	Smooth Surface

Table 6 — Mechanical properties of epoxidized oil based films

Sample code	Thickness (µm)	Hardness (pencil grade)	Adhesion (ASTM D3359)	Flexibility (mandrel bend mm)	Impact resistance (cm.kg)
ERSG1	73	2H	5B	1.5	25
ERSG2	70	F	4B	2.2	30
ERSG3	65	HB	3B	3.8	36

from ERSG1 blend provides better mechanical protection.

Adhesion

The thin film prepared from ERSG1 is superior to adhesion (Table 6) with 5B indicating no film removed. The blend ERSG2 showed good adhesion 4B while blend ERSG3 slightly flaking along the edges of the cut 3B. The improved adhesion in ERSG1 is due to better cross-linking density and fatty acid composition contributing to stronger interfacial bonding with the substrate.

Flexibility

The results showed (Table 6) that the film derived from ERSG1 blend have 1.5 mm flexibility with no visible crack even when bent over a 6 mm Mandrel. The blend ERSG2 also showed good flexibility with 2.2 mm, but developed micro cracks at 4 mm radius. The film from ERSG3 blend showed 3.8 mm of reduced flexibility, with visible cracking indicating increased brittleness .These differences may be due to variation in epoxidized oil structure and fatty acid unsaturation, which influences the polymer chain and cross lining density. The coating from ERSG1 blend have superior flexibility.

Impact resistance

The impact resistance of the thin film decreases in the order ERSG3 > ERSG2 > ERSG1, ERSG3 exhibited the highest impact resistance showing no visible cracking or loss of adhesion. This is due to its lower crosslink density and higher proportion of SFO and GO, which increases flexible chain. This increased flexibility allows the coating to deform. ERSG2 showed moderate impact resistance having sufficient toughness and rigidity. The balance between flexible segments and crosslink structure allow to absorb some energy while still resist deformation .The film of sample ERSG1 showed the lowest impact resistance because it contain large amount of RBO due to which it has high cross link density and enhances barrier properties but it also make the coating less capable of deformation leading to brittleness of the film.

Water resistance

Water resistance of films prepared from epoxidized oil derived from discarded oil blend is in order ERSG1 >ERSG2 >ERSG3. The film from ERSG1 show highest water resistance, maintaining its gloss, adhesion, and mechanical properties even after prolonged immersion. This is due to its higher RBO content, which after epoxidation and curing gives more density cross linked network with few polar sites. The decrease in polarity and lower free volume hinder water diffusion through the coating, therefore decrease hydrolytic degradation. ERSG2 shown moderate resistance, to water and contained more accessible polar groups than ERSG1, allowing slow water entering in the film. In case of ERSG3 show lowest water resistance prolonged immersion caused visible surface dullness, slight, blistering and reduced adhesion Thus behaviour is due to higher proportion of SFO and GO which on epoxidation gives networks of lower cross linked density causes water uptake by the film.

Acid, alkali and solvent resistance

Resistance to acid, alkali and solvent of the film formed by epoxidized oil is in order ERSG1 > ERSG2 > ERSG3 (Table 7). This pattern directly correlates with the proportion of RBO in the blend, which contains a higher proportion of long chain unsaturated fatty acids and a higher oxirane oxygen content after epoxidation. These factors favour the formation of a denser epoxy amine cross linked network during curing, thereby reducing the free volume for chemical reactions.

In the acid resistance test (5%HCl), ERSG1 based coating restricted acid diffusion and not affected by HCl

Table 7 — Chemical Resistance of epoxidized oil based films

Chemicals Used Days	ERSG1			ERSG2			ERSG3		
	2	4	6	2	4	6	2	4	6
Distilled Water	A	A	A	A	C	B	A	C	B
5% HCI	A	B	B	B	B	C	B	C	C
5% NaOH	B	C	C	B	D	C	B	C	D
Butanol	B	D	C	B	C	D	B	C	C
Mineral turpentine oil	C	C	D	C	D	E	D	C	E
Toluene	B	C	E	C	D	D	B	D	C

Whereas, A = Film not affected, B = Loss of gloss, C = Loss in colour, D = Wrinkling and blistering, E =Film removed

which is due to dense cross linking. While open network in ERSG3 allowed faster penetration of acid and swelling on the coating was observed.

In the alkali resistance test (5%NaOH), ERSG1 coatings remains unchanged indicating minimum hydrolysis of ester bonds, while ERSG3 showed swelling due to saponification of ester linkages facilitated by higher oil absorption and low crosslink density that is why the film from ERSG3 show visible swelling.

In case of solvent resistance such as toluene and mineral turpentine oil ERSG1 has lightly packed molecular structure and have minimum swelling due to solvent, while ERSG3 undergo significant softening and gloss loss due to solvent induced plasticization. Mineral turpentine oil being less effective to the coating, toluene caused moderate surface dullness in ERSG2, but ERSG3 is degraded by turpentine and toluene both.

Conclusion

The study on the film properties of epoxidized oil prepared from blended rice bran oil, sunflower oil and groundnut oil demonstrated that discarded frying oils, after chemical modification, can be effectively utilized as a sustainable raw material for coating applications. The film developed from epoxidized resins showed desirable properties such as adequate thickness, good hardness, adhesion, flexibility and impact resistance along with uniform transparency and glossy surface appearance. Among the different blend ratios studied, variations in mechanical and surface properties were strongly influenced by the fatty acid composition, degree of epoxidation, and secondary oxidation products in the oil. Coating obtained from higher proportion of rice bran oil exhibited better hardness and resistance to deformation, here as increased sunflower oil and ground nut oil contributed to improved flexibility and adhesion. Overall, the coatings prepared from epoxidized resin displayed a balanced combination of protective and aesthetic qualities, with good water and oil resistance, transparency and stable film forming ability. Finally, it can be concluded that epoxidized oil coatings with high RBO content suit wood, metal, packaging, automotive, and decorative uses due to durability, flexibility, adhesion, and eco-friendliness.

Acknowledgement

The authors gratefully acknowledge the Principal of the college for providing the necessary research facilities and IIT Kanpur for carrying out the IR analysis.

Conflict of Interest

The authors declare that they have no conflict of interest.

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