CHAPTER 4
CHAPTER 4

CROSS LINKED BIOPOLYMERS FROM SESAME OIL

4.1 INTRODUCTION

The scarcity of non renewable resources encouraged the scientific community to develop and commercialize new biobased products that can alleviate the wide-spread dependence on fossil fuels and, enhance security, the environment and the economy. [203] Natural oils are considered to be the most important class of renewable sources.[204] The main component of the triglyceride vegetable oils are saturated and unsaturated fatty acids. Although they have double bonds which can be used as reactive sites in coatings, for obtaining high performance polymeric materials the introduction of more reactive functional groups, such as hydroxyl, epoxy or carboxyl groups, is much more suitable.[205,206]

Plant oils are predominantly made up of triglyceride molecules. The triglyceride contains many active sites such as the double bond, the allylic carbons, the ester group, and the carbon alpha to the ester group. These active sites can be used to introduce polymerizable groups on the triglyceride, similar to the synthesis of petroleum-based polymers. [207]. Vegetable oils have been used in paints and coatings for centuries, because the unsaturated oils can oligomerize or polymerize when exposed to the oxygen in air.[208] In recent years, biorenewable fuels, mainly biodiesel, which can be used as an alternative engine fuel, have been prepared from vegetable oils by pyrolysis, catalytic cracking, and transesterification.[209]

Sesame oil (also known as gingelly oil or til oil) is an edible vegetable oil and is acquired from the seeds of Sesamum indicum plant. It naturally has yellow color, nutty flavor, and contains plenty of nutrients. Sesame oil is mainly composed of triglycerides of the
singly saturated oleic acid (43%), doubly saturated linoleic acid (35%), palmitic acid (11%) and stearic acid (7%) [210] (figure 4.1). Sesame oil is considered as semi drying oil and used for cooking. Besides for cooking, the oil is possibly applied topically for cosmetic purpose, especially skin health. Recently, a range of thermosets have been prepared by the cationic copolymerization of olive, peanut, sesame, canola, corn, soybean, grape seed, sunflower, low-saturation soy, safflower, walnut, and linseed oils with ST and DVB.[211]

![Figure 4.1](image.png)

Figure 4.1 Representative triglyceride found in sesame oil, a 86rimester (triglyceride) derived of linoleic acid and oleic acid.

This work report the synthesis and characterization of cross linked biopolymers from sesame oil by the polymerization of alkyd resin obtained from sesame oil monoglyceride and cyclohexane dicarboxylic anhydride with methyl acrylate, methyl methacrylate, vinyl acetate and N-vinyl pyrrolidone co-monomers.
4.2 RESULTS AND DISCUSSION

4.2.1 Physiochemical studies

The physiochemical parameters like specific gravity, iodine value, hydroxyl value, saponification value, acid value and intrinsic viscosity for the sesame oil, monoglyceride of sesame oil and the resin were calculated as per the standards and are given in table 4.1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sesame oil</th>
<th>Monoglyceride</th>
<th>Resin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>0.909</td>
<td>1.035</td>
<td>1.33</td>
</tr>
<tr>
<td>Iodine value</td>
<td>114.3</td>
<td>73.66</td>
<td>68.02</td>
</tr>
<tr>
<td>Hydroxyl value</td>
<td>0.17</td>
<td>22.8</td>
<td>12.89</td>
</tr>
<tr>
<td>Saponification value</td>
<td>192.5</td>
<td>120</td>
<td>98.5</td>
</tr>
<tr>
<td>Acid value</td>
<td>5.6</td>
<td>6.4</td>
<td>26</td>
</tr>
<tr>
<td>Viscosity</td>
<td>0.003</td>
<td>0.017</td>
<td>0.007</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>872.7</td>
<td>1400</td>
<td>1705.58</td>
</tr>
</tbody>
</table>

On glycerolysis there are changes in the physiochemical parameters like specific gravity, iodine value, hydroxyl value, saponification value, acid value and intrinsic viscosity of the oil, monoglyceride and the alkyd resin of oil. Specific gravity increases for monoglyceride and resin when compared to oil. Decrease in iodine value indicates the reduction in number of double bonds for monoglyceride and resin. Higher the hydroxyl value
in monoglyceride indicates the formation of hydroxyl groups during glycerolysis reaction. Higher the saponification value of resin indicates the formation of more free or hydrolysable acid groups. Increase in acid value of resin clearly indicates the presence of free acid groups in resin when compared to the oil. Viscosity also increases on glycerolysis and is high for monoglyceride of oil.

4.2.2 Spectral analysis

The progress of the chemical reaction was studied by analyzing FT-IR, and H\textsuperscript{1}NMR spectra of the oil, monoglyceride and the resin.

4.2.2.1 FT-IR Spectroscopy

Figures 4.2, 4.3 and 4.4 show the FT-IR spectra of sesame oil, sesame oil monoglyceride and sesame oil monoglyceride cyclohexane dicarboxylate resin.

![Figure 4.2 FT-IR spectrum of sesame oil](image)

Figure 4.2 FT-IR spectrum of sesame oil
Figure 4.3 FT-IR spectrum of sesame oil monoglyceride

Figure 4.4 FT-IR spectrum of sesame oil monoglyceride cyclohexane dicarboxylate resin
In the FT-IR spectrum of sesame oil the peaks at 3007.44 cm\(^{-1}\), 2952.48 cm\(^{-1}\) and 2855.1 cm\(^{-1}\) correspond to the C-H stretching frequencies for olefinic, methylene and methyl groups. The peak at 1745.26 cm\(^{-1}\) corresponds to the C=O stretching frequency of ester group. The peaks at 1460.81 cm\(^{-1}\), 1374.03 cm\(^{-1}\) and 722.21 cm\(^{-1}\) correspond to the C-H bending vibration of CH\(_2\) and CH\(_3\) groups. The peaks at 1238.08 cm\(^{-1}\) and 1163.83 cm\(^{-1}\) correspond to the C-C and C-O stretching vibrations. The presence of additional peak at 3473.17 cm\(^{-1}\) in the FT-IR spectrum of linseed oil monoglyceride corresponds to the presence of OH groups (i.e. confirms the formation of partial glycerides). The peak at 3471.24 cm\(^{-1}\) in the FT-IR spectrum of the resin indicates the terminal hydroxyl groups in the alkyd resin.

4.2.2.2 \(^1\text{H}\) NMR Spectroscopy

Figures 4.5, 4.6 and 4.7 show the \(^1\text{H}\) NMR spectrum of sesame oil, sesame oil monoglyceride and sesame oil monoglyceride cyclohexane dicarboxylate resin.

Figure 4.5 \(^1\text{H}\) NMR spectrum of sesame oil
Figure 4.6 $^1H$ NMR spectrum of sesame oil monoglyceride

Figure 4.7 $^1H$ NMR spectrum of sesame oil monoglyceride cyclohexane dicarboxylate resin
In the $^1$H NMR spectrum of sesame oil, the peak at 0.834 corresponds to the terminal methyl protons, the peaks at 1.252 and 1.562 correspond to CH$_2$ and CH protons, the peaks at 1.990 and 2.257 for protons in allylic and bis allylic carbons, the peak at 2.715 for protons in CH$_2$-O carbon, the peaks at 4.102 and 4.262 for the methylene protons in the ester group and the peak at 5.285 corresponds to the olefinic protons (protons of glycerol backbone). In the $^1$H NMR spectrum of sesame oil monoglyceride, the additional peak at 5.1 for the OH protons which confirms the formation of monoglyceride and the multiplet peak at 3.2 - 3.8 corresponds to the CH$_2$ protons attached to the OH group. In the $^1$H NMR spectrum of resin, the multiplet at 4 – 4.3 corresponds to the protons in the cyclohexane ring.

4.2.3 Thermal analysis

Thermal stability of the polymers was investigated by thermo gravimetric analysis (TGA). The thermal analysis of the biopolymers prepared from sesame oil was determined by TG–DTA analysis. Thermo gravimetric analysis (TGA) was performed by Perkin’s Elmer thermo gravimetric analyzer over the temperature ranging from 30 to 700 °C at a heating rate of 10 °C/min under nitrogen gas atmosphere.

Figures 4.8, 4.9, 4.10 and 4.11 are the TG-DTA curves of SESMGMA, SESMGMMA, SESMGVA and SESMGVP which show the decomposition behaviour of the polymer samples under nitrogen atmosphere. Two distinct temperature regions are observed in the TGA curve where the samples experienced significant weight loss (150-250°C and 300-450°C). Figures 4.12, 4.13, 4.14 and 4.15 are the TG-DTG curves of the polymer samples SESMGMA, SESMGMMA, SESMGVA and SESMGVP, which show the temperature at which weight loss is maximum.
It is clear from the figure that most of the unreacted free oil disappears at the temperature between 150 and 250°C (stage 1), i.e. this region corresponds to the evaporation of the unreacted free oil. On the other hand, the insoluble substances were found to be highly cross linked thermosets that decompose at temperatures greater than 300°C (stage 2). This decomposition stage corresponds to the carbonization of the cross linked polymer network. Stage-I in the TGA curves involves two major steps, i.e. diffusion of the free oil to the surface of the bulk polymer and subsequent evaporation. The diffusion of the free oil is retarded by highly crosslinked materials, but the evaporation of the free oils from the polymer surface occurs rather rapidly at high temperatures. From the preceding results, it is clear that the thermal stability of the polymers is limited by the first decomposition stage in the TGA thermograms, which is directly related to the amount of unreacted free oil in the bulk polymer.

In this study, the temperature at 10% weight loss is selected as a reference for evaluating the thermal stability of each polymer material. At high oil concentration in the original composition, the temperature at 10% weight loss of the resulting polymers appears to be relatively independent of the oil concentration. The temperature at 10% weight loss is therefore predominantly determined by the diffusion process, rather than the subsequent evaporation. However, when the amount of unreacted free oil present in the bulk polymer is very high, diffusion of the free oil to the polymer surface occurs rapidly, minimizing the difference in the temperature of 10% weight loss at these relatively high oil concentrations. From the TGA curve it is known that 10% weight loss occur in the first stage of decomposition and 50% weight loss occur in the II stage of decomposition. Table 4.2 shows the temperature at which the polymer samples shows 10% and 50% weight loss during the thermo gravimetric analysis.
Figure 4.8 TG-DTA curve of sesame oil monoglyceride cyclohexane dicarboxylate – methyl acrylate (SESMGMA) copolymer

Figure 4.9 TG-DTA curve of sesame oil monoglyceride cyclohexane dicarboxylate – methyl methacrylate (SESMGMMA) copolymer
Figure 4.10 TG-DTA curve of sesame oil monoglyceride cyclohexane dicarboxylate – vinyl acetate (SESMGVA) copolymer

Figure 4.11 TG-DTA curve of sesame oil monoglyceride cyclohexane dicarboxylate – N-vinyl-2-pyrrolidone (SESMGVP) copolymer
Figure 4.12 TG-DTG curve of sesame oil monoglyceride cyclohexane dicarboxylate – methyl acrylate (SESMGMA) copolymer

Figure 4.13 TG-DTG curve of sesame oil monoglyceride cyclohexane dicarboxylate – methyl methacrylate (SESMGMMA) copolymer
Figure 4.14 TG-DTG curve of sesame oil monoglyceride cyclohexane dicarboxylate – vinyl acetate (SESMGVA) copolymer

Figure 4.15 DTG curve of sesame oil monoglyceride cyclohexane dicarboxylate – N-vinyl-2-pyrrolidone (SESMGVP) copolymer
Table 4.2 TGA data of polymer samples from sesame oil

<table>
<thead>
<tr>
<th>Polymer sample</th>
<th>Temperature (ºC)</th>
<th>10% weight loss</th>
<th>50% weight loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>SESMGMA</td>
<td>220</td>
<td>375</td>
<td></td>
</tr>
<tr>
<td>SESMGMMA</td>
<td>225</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>SESMGVA</td>
<td>220</td>
<td>360</td>
<td></td>
</tr>
<tr>
<td>SESMGVP</td>
<td>180</td>
<td>360</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.3 DTG data of polymer samples from sesame oil

<table>
<thead>
<tr>
<th>Polymer sample</th>
<th>Decomposition Temperature (ºC)</th>
<th>I Stage</th>
<th>II Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SESMGMA</td>
<td>227.46 401.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SESMGMMA</td>
<td>241.68 393.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SESMGVA</td>
<td>231.64 402.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SESMGVP</td>
<td>225.12 410.01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DTA curves of the polymer samples SESMGMA, SESMGMMA, SESMGVA and SESMGVP shows an endothermic peak around 120ºC which corresponds to the melting point of the polymer network and the exothermic peak around 400ºC corresponds to the decomposition temperature of the polymer.
The study of TGA is supplemented by the study of its first derivative (DTG) curves. The DTG curves show the rate of thermal decomposition (mg/min) with respect to temperature. The DTG curve in Figure 4.12 shows that the polymer SESMGMA has two significant peaks at 227.46°C and 401.82°C with corresponding 0.225mg/min and 0.579 mg/min rate of decomposition. The DTG curves in Figures 4.13, 4.14 and 4.15 show similar peaks at 241.68°C with 0.453 mg/min and at 393.12°C with 0.862 mg/min rate of decomposition for SESMGMA, at 231.64°C with 0.574 mg/min, and 402.45°C with 1.098 mg/min rate of decomposition for SESMGVA and at 225.12°C and 410.01°C for SESMGVP polymer.

4.2.4 Mechanical studies

The tensile strength of the biopolymers prepared by the polymerization of sesame oil monoglyceride cyclohexane dicarboxylate with co-monomers like methyl acrylate, methyl methacrylate, vinyl acetate and N-vinyl-2-pyrrolidone was determined using Instron UTM; 10 ton static Universal Testing Machine. Tensile testing involves applying a constant rate of tensile load to a test sample up to the point of failure. The process creates a stress/strain curve showing how the material reacts throughout the test process. The data generated during the test is used to determine tensile strength, yield strength and ductility for polymer characterization. The values represented were an average mean of about 4-5 samples.

The crosslink densities, $v_s$, were determined from the rubbery modulus plateau based on the theory of rubber elasticity $E' = 3v_sRT$ [212, 213]. Where $E'$ is the storage modulus (Young’s) of cross linked polymer in the plateau region, $R$ is the universal gas constant (8.314 J·mole$^{-1}$·K$^{-1}$) and $T$ is the absolute temperature (K).
From the cross link density molecular weight between cross links can be determined using the relation, Cross link density, $n_c = \frac{E}{3RT} = \frac{\rho}{M_c}$, Where $\rho$ is elastomer density and $M_c$ is molecular weight between cross links.

Molecular weight between cross links $= \frac{1}{\text{Cross link density}}$

Table 4.4 Mechanical properties of the biopolymers

<table>
<thead>
<tr>
<th>Polymer sample</th>
<th>Cross link density ($\times 10^{-3}$)</th>
<th>Mol.wt between cross links (mol$^3$)</th>
<th>Tensile strength $\times 10^5$ Pa</th>
<th>% of elongation</th>
<th>Young’s Modulus $\times 10^5$ Pa</th>
<th>Shore D hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>SESMGMA</td>
<td>0.715</td>
<td>1398.6</td>
<td>5.94</td>
<td>111.35</td>
<td>54</td>
<td>59.4</td>
</tr>
<tr>
<td>SESMGMMMA</td>
<td>2.726</td>
<td>366.83</td>
<td>17.65</td>
<td>111.75</td>
<td>206.05</td>
<td>60.2</td>
</tr>
<tr>
<td>SESMGVA</td>
<td>1.154</td>
<td>866.55</td>
<td>3.47</td>
<td>104.1</td>
<td>87.18</td>
<td>58.3</td>
</tr>
<tr>
<td>SESMGVP</td>
<td>1.215</td>
<td>823.04</td>
<td>4.64</td>
<td>105.64</td>
<td>91.85</td>
<td>58.5</td>
</tr>
</tbody>
</table>

The new polymeric materials exhibited tensile stress–strain behavior relatively to plastics. Chain length is directly related to polymer strength and chain branching strongly affects the mechanical properties of the polymers. The mechanical properties of the polymer samples prepared from sesame oil are shown the table 4.4. From the data it is clear that the polymer samples prepared having high tensile strength and modulus relative to other thermosetting plastics. Comparing the polymer samples prepared from sesame oil, methyl methacrylate containing polymer is having high tensile strength and modulus and vinyl
acetate containing polymer having low tensile strength. It is observed that the tensile strength and modulus of elasticity of the polymers increases with increasing cross link density.

Hardness of the polymer samples prepared was measured by Shore D hardness tester (HT-6510D). This polymer testing method determines a material’s hardness value or resistance to indentation by penetration of an indenter into the test sample. It is observed that the hardness of the polymers also increases with increasing cross link density.

4.2.5 Swelling analysis

It is well known that swelling is induced by the electrostatic repulsion of ionic charges present within the network. Cross link density directly affects the mechanical deformation of the polymers ie, diffusion of solvents decreases due to increased level of cross-linking. The increasing cross-link density restricts the swelling of the polymers. It is expected that polymers with higher cross-link density would provide numerous water channels for the diffusion of water, but the water content decreases due to increased level of cross-linking. The high cross-link density restricts the movement of polymer segment.

The swelling analysis of the polymeric samples were carried out in different solvents viz., saline (20% NaCl), alkaline (2% NaOH), acidic (2%H2SO4) and toluene. The polymeric samples were allowed to remain in the solution for 72 hours at room temperature and then weighed as soon as they were removed from the solvent.

All the polymeric samples show minimum swelling in alkaline solution and significant swelling in toluene, acidic and brine (NaCl) solution. Comparing the swelling property of all the polymers, SESMGVP shows minimum swelling in all the solvents. In the polymers from sesame oil, methyl acrylate containing polymer possess lower cross link density and it shows significant swelling when compared to the N-vinyl-2-pyrrolidone
containing polymer which possess higher cross link density than the polymer sample prepared from linseed oil.

Figure 4.16 Swelling of SESMGMA in various solvents

Figure 4.17 Swelling of SESMGMMA in various solvents
Figure 4.18 Swelling of SESMGVA in various solvents

Figure 4.19 Swelling of SESMGVP in various solvents
Figures 4.16, 4.17, 4.18 and 4.19 show the swelling ratios at different time intervals for the polymer samples in different solutions which represent the time dependence of the swelling ratios. A sharp rise in $q_v$ values is observed at the early stages of swelling. After particular period, the $q_v$ values show little change (almost remain constant). This may be explained in terms of the catastrophic rupture of the polymer network due to the internal stress caused by diffusion of the liquid into the polymer network. The increasing cross-link density restricts the swelling of the polymers.

4.2.6 Chemical resistance

The extent to which polymers are subjected to attack by chemicals is determined by a number of parameters, related both to the chemical and the polymer involved. Chemical attack can cause polymers to partially dissolve, plasticize, react chemically and absorb these chemicals. These events will not always lead to product failure, but the mechanical properties may be reduced and the weight of the products may change.

Chemical resistance of the newly prepared polymer samples were studied by immersing the polymer samples in various solvents such as CCl$_4$, CHCl$_3$, diethyl ether, benzene, toluene, H$_2$O$_2$, HCl, ethanol, H$_2$O, NaCl etc. and measuring the dimensional changes after 1 week and 4 weeks[160]. The weight loss also measured after 30 days.

All the polymeric samples prepared are highly stable but undergoes slight degradation in H$_2$O, ethanol, NaCl, H$_2$O$_2$ and acetone. (Table 4.5) The samples SESMGMA and SESMGMAA are highly stable except in ethanol and NaCl. The samples SESMGVA and SESMGVVP undergo slight degradation in H$_2$O, ethanol, NaCl, H$_2$O$_2$ and acetone. The dimension of the polymer samples immersed in HCl, H$_2$O and NaCl did not change even after 4 weeks as a result of higher cross-linking density, but the dimension of the polymers
immersed in organic solvents (CCl₄, diethyl ether and CHCl₃) changed after 1 week. The
dimension could not be measured after 4 weeks due to their fragility.

Table 4.5 Weight loss the polymers in various solvents

<table>
<thead>
<tr>
<th>Solvents</th>
<th>SESMGMA</th>
<th>SESMGMMA</th>
<th>SESMGVA</th>
<th>SESMGVP</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Ethanol</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>HCl</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>H₂O₂</td>
<td>9</td>
<td>10</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>NaCl</td>
<td>10</td>
<td>0</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Benzene</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Toluene</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Acetone</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>CCl₄</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CHCl₃</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

In addition, the polymers prepared have higher chemical resistance in non polar
organic solvents (toluene, CCl₄ and CHCl₃) than in polar organic solvents (ethanol). This fact
indicates that the solvents clearly interacted with the resin as a consequence of their similar
polarity ie polar groups containing polymers are usually dissolve in polar solvents and
chemically resistance to non polar solvents.
The comparison of stability of polymers SESMGMA, SESMGMMA, SESMGVA and SESMGVP towards various chemicals was shown in the figure 4.20.

![Stability of polymers in various solvents](image)

Figure 4.20 Chemical resistances of polymers in various chemicals

### 4.2.7 SEM analysis

Polymer morphology is a microscale property that is largely dictated by the amorphous or crystalline portions of the polymer chains and their influence on each other. Surface properties can have an enormous effect on the success or failure of biomaterials. The properties that are of interest in the characterization of biomaterial surfaces include the chemical structure, the hydrophilicity or hydrophobicity, the presence of ionic groups, the morphology (i.e. the domain structure), and the topography (i.e. the surface roughness, planarity, and feature dimensions).

SEM is commonly used for studying both the surface morphology and cellular response of biomaterials. Figures 7.7, 7.8, 7.9 and 7.10 show the SEM micrographs of the
polymers SESMGMA, SESMGMMA, SESMGVA and SESMGVP. It is concluded from the figures that, in all polymers there is homogeneity in the distribution of resin and the monomer.

4.3 CONCLUSION

1. A variety of cross linked bio degradable polymers have been synthesized by the free radical copolymerization of sesame oil monoglyceride cyclohexane dicarboxylate with methyl acrylate, methyl methacrylate, vinyl acetate and N-vinyl-2-pyrrolidone as co-monomers.

2. The polymers are found to be typical thermosetting materials. They exhibited good tensile stress–strain behavior relatively to plastics.

3. Two distinct decomposition stages are found upon thermogravimetric analysis, which correspond to evaporation of the unreacted free oil present in the bulk polymer and carbonization of the crosslinked polymer. The thermal stability of the polymers is mainly determined by the amount of the unreacted free oil present in the bulk polymer.

4. The polymers prepared from sesame oil ie SESMGMA and SESMGMMA are highly stable except in ethanol and NaCl and the samples SESMGVA and SESMGVP undergoes slight degradation in H$_2$O, ethanol, NaCl, H$_2$O$_2$ and acetone.

5. From the swelling analysis, it is observed that all the polymeric samples prepared from sesame oil also show significant swelling in acid, NaCl and toluene in the early stage except in NaOH. Comparing the swelling property of all the polymers prepared from sesame oil SESMGVP shows minimum swelling in all the solvents.