Chapter III

Synthesis of Hydrophobic Compounds Derived from

Natural Resource Materials
3.1 Introduction:

Various hydrophobic compounds have been used in the past to synthesize HMPs.\textsuperscript{1} For example, long chain alkyl amines such as dodecyl amine, hexadecyl amine and octadecyl amine have been used in the hydrophobic modification of synthetic water-soluble polymer such as, poly(acrylic acid) [PAA], n-butyl methacrylate, n-butyl acrylate, dodecyl methacrylate, octadecyl methacrylate. Long chain alkyl epoxides namely, 1, 2-epoxydecane/1, 2-epoxydodecane, alkyl halides, acyl halides, alkyl isocyanates, alkyl anhydrides or aliphatic acid chlorides have been used to hydrophobically modified ethyl hydroxyl ethyl cellulose (EHEC) and carboxymethyl cellulose\textsuperscript{2} (CMC, Natural polymers).

The replacement of hydrocarbons with perfluoroalkyl groups in the synthesis of HMPs is also of specific interest, since the hydrophobic character of perfluoroalkyl groups is more pronounced compared to their hydrocarbon analogues and are found to be more effective for hydrophobic associations. Fluorocarbon modified EHEC have been reported in the literature.\textsuperscript{3} Details of some of the hydrophobes along with their chemical structure and hydrophobic modification using specific polymers is given in Table 3.1.

**Table 3.1. Different hydrophobic compounds used for the modification of water-soluble polymers along with references.**

<table>
<thead>
<tr>
<th>Hydrophobes and chemical structure</th>
<th>Water-soluble polymers</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{H}_3\text{C}-(\text{CH}_2)_n-\text{NH}_2$</td>
<td>Poly(acrylic acid), poly(aspartic acid), alginates</td>
<td>4-6</td>
</tr>
<tr>
<td>Long chain alkyl amines $n = 1, 2, 3 \ldots$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{H}_3\text{C}-(\text{CH}_2)_n-\overset{\text{O}}{\text{-}}$</td>
<td>Ethyl hydroxyl ethyl cellulose (EHEC), carboxy methyl cellulose (CMC)</td>
<td>7, 8</td>
</tr>
<tr>
<td>Long chain alkyl epoxides $n = 1, 2, 3 \ldots$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{H}_3\text{C}-(\text{CH}_2)_n-\text{X}$</td>
<td>Ethyl hydroxyl ethyl cellulose (EHEC), carboxymethyl</td>
<td>7, 8, 9</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Long chain alkyl halides</th>
<th>cellulose (CMC), poly(vinyl alcohol)</th>
<th>7, 8, 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/Ar—CO—X</td>
<td>Ethyl hydroxyl ethyl cellulose (EHEC), carboxymethyl cellulose (CMC), poly(ethylene glycol)</td>
<td></td>
</tr>
<tr>
<td>R/Ar—CO—X</td>
<td>Ethyl hydroxyl ethyl cellulose (EHEC), carboxymethyl cellulose (CMC), poly(ethylene glycol)</td>
<td></td>
</tr>
<tr>
<td>H₃C—(CH₂)ₙ—NCO</td>
<td>Poly(ethylene glycol)</td>
<td>11</td>
</tr>
<tr>
<td>H₃C—(CH₂)ₙ—NCO</td>
<td>Ethyl hydroxyl ethyl cellulose (EHEC), poly(acrylic acid), poly(ethylene glycol)</td>
<td>7, 12, 13</td>
</tr>
<tr>
<td>H₃C—(CH₂)ₙ—NCO</td>
<td>Ethyl hydroxyl ethyl cellulose (EHEC), carboxymethyl cellulose (CMC)</td>
<td>7, 8</td>
</tr>
<tr>
<td>H₃C—(CH₂)ₙ—OH</td>
<td>Ethyl hydroxyl ethyl cellulose (EHEC)</td>
<td>7</td>
</tr>
<tr>
<td>H₃C—(CH₂)ₙ—CHO</td>
<td>Chitosan</td>
<td>14</td>
</tr>
</tbody>
</table>

Long chain acyl/aryl halides

Long chain alkyl isocyanates

Long chain perfluoro compounds

Long chain alkyl anhydrides

Long chain alcohol

Long chain aldehyde
Although large number of hydrophobic compounds have been synthesized and used in the preparation of HMPs/APs, our interest has been in the design and synthesis of new hydrophobic compounds from renewable resource materials such as, cashew nut-shell liquid (CNSL) and gallic acid (GA).

### 3.1.1 Cashew nut-shell liquid [CNSL]:

Cashew nut-shell liquid is a byproduct in the cashew processing industry and abundantly available. The total production of CNSL worldwide amounts to ~ 1, 25, 000 TPA. CNSL is a product of cashew tree, *Anacardium occidentale* and present in the pericarp of the cashew nut. Cashew tree is cultivated globally in tropical areas such as Brazil, India, Bangladesh, Tanzania, Kenya, tropical regions of Africa and South East and Far-East Asia. Number of methods such as hot-oil bath and roasting are used to extract CNSL from nuts. Steam distillation, solvent extraction techniques are also used to obtain oil from nuts.\(^{16-17}\) (Figure 3.1)

![Figure 3.1. Source of CNSL.](image)
Industrial grade CNSL is reddish brown in colour and consists of naturally occurring non-isoprenoid phenolic compounds such as: anacardic acid, cardanol and 2-methyl cardol. (Figure 3.2)

![Chemical structures of CNSL constituents](image)

**Figure 3.2. Constituents of cashew nut-shell liquid. (CNSL)**

Commercial grade CNSL contains hardly any anacardic acid because of decarboxylation during roasting process, which converts anacardic acid to cardanol. The unsaturated C-15 chain along with the phenolic moiety in CNSL has offered variety of possibilities of reaction of CNSL such as, hydrogenation, sulfonation, nitration, halogenation, etherification, esterification, epoxidation, phosphorylation which have been documented in the literature. 18-23

3.1.2 Gallic acid:

Gallic acid (3, 4, 5-trihydroxybenzoic acid) is found in nature in gallnuts, sumac, tea leaves and oak bark in the form of gallotannins (Figure 3.3). This class of tannins is also called as hydrolysable tannins. Gallotannins are simple polygalloyl esters of glucose that has five ester linkages and consists of aliphatic hydroxyl groups of the core sugar of gallic acid.
Harad, Harda, Indian gall-nut, Ink nut are the common names for the tree shown in Figure 3.3. Botanical name of the plant is Terminiia chebula, available in Northern and Central India. The fruit of the plant is called Mayrabolan.

Hydrolysis of gallotannins (pentagalloyl glucose) with strong acid such as H₂SO₄ results into gallic acid and the core polyol. Gallic acid (F. W. = 170.12, M. P. = 253 °C) is a white or yellowish-white solid and is soluble in alcohol, ether and in boiling water. It is odorless and has acid taste. It is used in inks, photography and pharmaceuticals. It has antifungal, antiviral activity and used as antioxidant. It is also used in ointments.24-25 (Figure 3.4, 3.5)

![Figure 3.4 Structure of gallotannins.](image)

![Figure 3.5 Structure of gallic acid.](image)
In this chapter, the synthesis and characterization of four hydrophobic compounds namely, (I) 3-pentadecyl cyclohexyl amine [3-PDCA], (II) 3-pentadecyl cyclohexane carbaldehyde [3-PDCAL] from CNSL and (III) methyl 3, 4, 5-tris (n-octyloxy) benzoate [MGC₃], (IV) methyl 3, 4, 5-tris (n-dodecyloxy benzoate) [MGC₁₂] from gallic acid have been reported.

3.2 Experimental:

3.2.1 Materials:

3-Pentadecyl phenol [3-PDP], ruthenium on carbon [Ru-C], lithium aluminium hydride [LiAlH₄], n-octyl bromide [n-C₈H₁₇Br] and n-dodecyl bromide [n-C₁₂H₂₅Br], methoxy methyl triphenyl phosphonium chloride [C₂₀H₂₀OClP] were purchased from Aldrich chemical company, USA and used as received. Analytical grade pyridine, chromium trioxide [CrO₃], Celite-545, pyridinium chlorochromate [C₅H₆NO₃ClCr], potassium t-butoxide [t-BuOK], tetrabutyl ammonium bromide [C₁₂H₂₅NB], potassium carbonate, p-toluene sulfonic acid, sodium sulfate, sodium bicarbonate, silica gel, hydroxyl amine hydrochloride, hydrochloric acid, isopropanol, ethanol, dichloromethane, diethyl ether, dioxane were procured from Merck, India and were used as received.

3.3 IR and NMR spectroscopy:

¹H and ¹³C NMR spectra were recorded using spectrometers operating at ¹H NMR frequency of 200, 400 and 500 MHz (Bruker AV-200, DRX-400, DRX-500 NMRX All the spectra were recorded in CDCl₃. IR spectra were obtained using FT-IR spectrometer. (Schimatzu, Perkin Elmer)

3.4 Synthesis of 3-PDCA:

3-PDCA was synthesized from 3-pentadecyl phenol (3-PDP) in four steps: (i) reduction of 3-PDP to 3-pentadecyl cyclohexanol (ii) oxidation of 3-pentadecyl cyclohexanol to 3-pentadecyl cyclohexanone (iii) conversion of 3-pentadecyl cyclohexanone to 3-pentadecyl cyclohexane oxime (iv) reduction of 3-pentadecyl cyclohexane oxime to 3-pentadecyl cyclohexyl amine.
3.4.1 Reduction of 3-pentadecyl phenol (1) to 3-pentadecyl cyclohexanol (2):

Into a Paar reactor, 3-pentadecyl phenol (35.0 g, 0.115 mol) was dissolved in propan-2-ol (140 ml). To the above solution, ruthenium on carbon (Ru-C, 1.05 g) was added under stirring. Reactor was maintained at hydrogen (H₂) pressure of 900 psi and 100 °C temperature for 2 h. Catalyst was separated by passing the reaction mixture through a bed of silica gel. Filtrate containing 3-pentadecyl cyclohexanol was concentrated on rotary evaporator to obtain dry powder. Conversion of 3-pentadecyl phenol to 3-pentadecyl cyclohexanol is shown in Scheme 3.1. Yield = 35.4 g (99 %).

3.4.2 Oxidation of 3-pentadecyl cyclohexanol (2) to 3-pentadecyl cyclohexanone (3):

Into a 5 liter three necked round bottom flask equipped with a mechanical stirrer, 3-pentadecyl cyclohexanol (125.0 g, 0.04 mol) was dissolved in 1.5 liter dichloromethane. To this solution pyridinium chlorochromate (PCC) (130.0 g 0.66 mol) mixed with silica gel (130 g) was added at 0 °C and stirred vigorously for 8 h at room temperature. Dichloromethane solution was filtered through a bed of mixture of silica gel and Celite-545 to remove the PCC residue. Dichloromethane solution was neutralized by washing with aqueous sodium bicarbonate solution followed by washing with water. Organic layer was dried over sodium sulfate. Solvent was evaporated on a rotary evaporator to obtain a white solid, 3-pentadecyl cyclohexanone. Crude product was recrystallized from methanol. Conversion of 3-pentadecyl cyclohexanol to 3-pentadecyl cyclohexanone is shown in Scheme 3.1. Yield = 117.0 g (94 %).

3.4.3 Conversion of 3-pentadecyl cyclohexanone (3) to 3-pentadecyl cyclohexane oxime (4):

Into a 500 ml three necked round bottom flask, 3-pentadecyl cyclohexanone (20.0 g, 64.82 mmol) was dissolved in ethanol (250 ml). To the above solution hydroxyl amine hydrochloride (9.01 g, 129.65 mmol) and pyridine (7.75 g, 114 mmol) were added and the reaction mixture was refluxed for 2 h. The reaction mixture was allowed to cool to room temperature and 100 ml distilled water was added with continuous stirring over a period of 0.5 h. The reaction mixture was extracted with diethyl ether (3 x 50 ml). Ether solution was washed with brine, water, separated and dried over anhydrous sodium.
sulfate. Solvent was removed using rotary evaporator and the product obtained was purified by recrystallization from methanol. Conversion of 3-pentadecyl cyclohexanone to 3-pentadecyl cyclohexane oxime is shown in Scheme 3.1. Yield = 16.8 g (81%).

3.4.4 Reduction of 3-pentadecyl cyclohexane oxime (4) to 3-pentadecyl cyclohexyl amine (5):

Into a 500 ml three necked round bottom flask equipped with a magnetic stirring bar, a reflux condenser, an addition funnel and an inlet for nitrogen gas was added lithium aluminium hydride (37.95 g, 278.2 mmol) and dry diethyl ether (250 ml). The reaction mixture was maintained at 0 °C and 3-pentadecyl cyclohexanone oxime (15.0 g, 46.36 mmol) dissolved in diethyl ether (200 ml) was added drop-wise over a period of 0.5 h under the nitrogen atmosphere. Reaction mixture was allowed to attain room temperature and further refluxed for 2 h under the nitrogen atmosphere. Reaction mixture was allowed cool to 0 °C and saturated aqueous solution of sodium sulfate (100 ml) was added. Resulting slurry was filtered through a Celite-545 column and the filtered semi-solid was washed with chloroform (3 x 100 ml). Combined filtrate and washings were dried over sodium sulfate and concentrated on rotary evaporator to obtain product. Conversion of 3-pentadecyl cyclohexane oxime to 3-pentadecyl cyclohexyl amine is shown in Scheme 3.1. Yield = 14.06 g. (98%).

3.5 Synthesis of 3-PDCAL:

The hydrophobic compound 3-PDCAL was also synthesized from 3-PDP. Same steps used for the preparation of 3-PDCA were followed till the preparation of 3-pentadecyl cyclohexanone. Then, the 3-pentadecyl cyclohexanone was converted to (E/Z)-1-(methoxy methylene)-3-pentadecyl cyclohexane which was further converted to 3-PDCAL.

3.5.1 Conversion of 3-pentadecyl cyclohexanone (3) to (E/Z)-1-(methoxy methylene)-3-pentadecyl cyclohexane (4):

Into a 1 liter three necked round bottom flask equipped with a reflux condenser, a suspension of methoxymethyl triphenyl phosphonium chloride (MMTPC) (54.72 g, 0.2 mole) in dioxane (560 ml) was stirred at 20 °C. A suspension of MMTPC in dioxane was...
stirred and potassium tertiary butoxide (18.18 g, 0.2 mole) was added to the mixture which changed reaction mixture red. (Slightly exothermic reaction) Reaction mixture was allowed to stir for 3 h and 3-pentadecyl cyclohexanone (10 g, 0.032 mole) was added. Reaction mixture was stirred at 20 °C for 1 h and then heated to reflux for 3 h. The mixture was allowed to cool, diluted with water (560 ml), extracted with diethyl ether. The conversion of the reaction was monitored by IR by the disappearance of the carbonyl frequency. (1711 cm⁻¹) Organic extracts were washed twice with water, dried over sodium sulfate and concentrated on rotary evaporator. Conversion of 3-pentadecyl cyclohexanone to (E/Z)-1-(methoxy methylene)-3-pentadecyl cyclohexane is shown in Scheme 3.2. Yield = 7.5 (75 %).

3.5.2 Conversion of (E/Z)-1-(methoxy methylene)-3-pentadecyl cyclohexane (4) to 3-pentadecyl cyclohexane carbaldehyde (5):

Into a 1 liter three necked round bottom flask equipped with a reflux condenser (E/Z)-1-(methoxy methylene)-3-pentadecyl cyclohexane (6.5 g, 0.019 mole) was dissolved in dioxane (400 ml). To the above mixture, p-toluene sulfonic acid (0.75 g, 0.0044 mole) was dissolved in water (80 ml) and added. Reaction mixture was refluxed for 16 h followed by cooling and dilution with water. (400 ml) The product was extracted with diethyl ether. All the extracts were washed with water, dried over sodium sulfate and concentrated on rotary evaporator. Product was yellow viscous oil. Conversion of (E/Z)-1-(methoxy methylene)-3-pentadecyl cyclohexane to 3-pentadecyl cyclohexane carbaldehyde is shown in Scheme 3.2. Yield = 5.85, (90 %).

3.6 Preparation of hydrophobic compounds from gallic acid:
3.6.1 Synthesis of methyl 3, 4, 5-tris octyloxy benzoate [MGC₈]:

Synthesis of MGC₈ consists of two steps:

(i) Conversion of gallic acid to methyl 3, 4, 5-trihydroxy benzoate (methyl gallate).

(ii) Conversion of 3, 4, 5-trihydroxy benzoate to methyl 3, 4, 5-tris (octyloxy) benzoate.
3.6.1.1 Preparation of methyl 3, 4, 5-trihydroxybenzoate (methyl gallate):

Into a 250 ml single necked round bottom flask equipped with a reflux condenser, gallic acid (10 g, 0.058 mol) was dissolved in methanol (150 ml). To the reaction mixture, thionyl chloride (9 ml, 0.076 mol) was added drop-wise through the addition funnel with stirring at 0 °C. The reaction mixture was refluxed at 65 °C for 4 h. Methanol was evaporated to obtain solid product which was dissolved in ethyl acetate and treated with NaHCO₃ solution (3 x 100 ml), saturated NaCl solution (2 x 100 ml) and water. Ethyl acetate solution was dried over sodium sulfate and then filtered through a short column of silica. Filtrate was concentrated using rotary evaporator and the product was dried under vacuum at room temperature. Conversion of gallic acid to methyl gallate is shown in Scheme 3.3. Yield = 82 %.

3.6.1.2 Preparation of methyl 3, 4, 5-tris(n-octyloxy) benzoate (MGC₈):

Into a 250 ml three necked round bottom flask equipped with a reflux condenser, methyl gallate (2 g, 0.0107 mol) was dissolved in 2-butanone (150 ml). A mixture of K₂CO₃ (8.99 g, 0.065 mol) and TBAB (0.17 g, 0.0054 mol) was triturated and added to the above solution. To the reaction mixture 1-bromooctane (6.29 g, 0.033 mol) was added and refluxed at 80 °C for 2 h. The progress of the reaction was monitored by TLC. Obtained brown mixture was allowed to cool to room temperature and water (120 ml) was added. Separated organic layer was washed with water (2 x 120 ml), 1 M HCl solution (2 x 120 ml) and again with water (2 x 120 ml). Organic layer was separated, dried over anhydrous sodium sulfate, filtered and concentrated using rotary evaporator to obtain yellow viscous oily product. Product was purified by flash column chromatography with hexane/ethyl acetate mixture (96:4, v/v) as an eluent. Purified product was yellow, viscous liquid. Conversion of methyl gallate to methyl 3, 4, 5-tris (octyloxy) benzoate and methyl 3, 4, 5-tris (dodecyloxy) benzoate is shown in Scheme 3.3. Yield = 92.5 %.

3.6.1.3 Synthesis of methyl 3, 4, 5-tris(n-dodecyloxy) benzoate [MGC₁₂]:

Using the same procedure mentioned above and replacing 1-bromo octane with 1-bromo dodecane, MGC₁₂ was prepared.
3.7 Results and Discussion:

3.7.1 Preparation of 3-Pentadecyl cyclohexyl amine [3-PDCA]:

3-PDCA was synthesized from 3-pentadecyl phenol [3-PDP]. 3-pentadecyl phenol was hydrogenated using hydrogen (H₂) as a reducing agent and ruthenium on carbon (Ru/C) as a catalyst. The obtained 3-pentadecyl cyclohexanol was oxidized to 3-pentadecyl cyclohexanone using pyridinium chlorochromate and silica gel as an oxidizing agent. 3-Pentadecyl cyclohexanone was then converted to 3-pentadecyl cyclohexane oxime using hydroxyl amine hydrochloride. Finally, 3-pentadecyl cyclohexane oxime was reduced to 3-pentadecyl cyclohexyl amine using lithium aluminium hydride as a reducing agent. The reaction pathway is shown in Scheme 3.1.

\[
\begin{align*}
\text{(1)} & \quad \text{H₂, Ru-C} \\
\text{Isopropanol, 2 h} & \quad \text{PCC, Flash silica} \\
\text{CHCl₃, 8 h, RT} & \quad \text{NH₂OH.HCl} \\
\text{Pyridine} & \quad \text{EtOH, 90°C, 2h} \\
\text{(2)} & \quad \text{C₁₅H₃₁} \\
\text{(3)} & \quad \text{C₁₅H₃₁} \\
\text{(4)} & \quad \text{C₁₅H₃₁} \\
\text{(5)} & \quad \text{C₁₅H₃₁} \\
\text{Reflux, 1.5 h} & \quad \text{LiAlH₄, Et-O-Et}
\end{align*}
\]


FT-IR spectrum of 3-PDCA (Figure 3.6) showed amine group (–NH₂) stretching frequency at 3392 cm⁻¹. Aliphatic side chain appeared at 2849 - 2924 cm⁻¹. –C–N bond stretching appeared in the range of 1033 - 1356 cm⁻¹.
Figure 3.6. FT-IR spectrum of 3-pentadecyl cyclohexylamine

$^1$H NMR spectrum of 3-PDCA (Figure 3.7) showed the terminal methyl (−CH$_3$) protons of the pentadecyl side (−C$_{15}$H$_{31}$) chain attached to the cyclohexyl ring at 0.82 ppm (triplet, −CH$_3$, 3 H). Methylene and methyne protons of the pentadecyl side chain and the cyclohexyl ring appeared in the range of 1.2 - 1.83 ppm (multiplet, (−CH$_2$)$_{13}$, 36 H). Proton of the cyclohexyl ring to which −NH$_2$ is attached, appeared at 2.55 and 3.00 ppm. (Singlet of singlet, (−CH), 1 H) Proton denoted as C exist in its equatorial and axial (C$_{eq,ax}$) conformation due to the ring flipping and experience different chemical environment. Therefore, for this proton two chemical shifts are observed (2.55 and 3.00 ppm).
Figure 3.7. $^1H$ NMR spectrum of 3-pentadecyl cyclohexyl amine

$^{13}$C NMR spectrum of 3-PDCA (Figure 3.8) showed the terminal methyl carbon of the pentadecyl side chain ($-C_{15}H_{31}$) of 3-PDCA at 14.02 ppm. Methylene carbons of the pentadecyl side chain and cyclohexyl ring appeared in the range of 20 - 45.94 ppm. Carbon to which amine group is attached appeared at 50.64 ppm.

Figure 3.8. $^{13}$C NMR spectrum of 3-pentadecyl cyclohexyl amine
The assignments of peaks in both $^1$H and $^{13}$C NMR spectra confirmed the structure of 3-PDCA.

### 3.7.2 Preparation of 3-pentadecyl cyclohexane carbaldehyde (3-PDCAL):

The hydrophobic compound, 3-pentadecyl cyclohexane carbaldehyde was prepared from 3-PDP a constituent of CNSL. The synthesis of 3-PDCAL from 3-PDP consists of 4 steps: (i) conversion of 3-PDP to 3-pentadecyl cyclohexanol using hydrogenation reaction with Ru/C as a catalyst under high pressure. (ii) in the second step, 3-pentadecyl cyclohexanol was converted to 3-pentadecyl cyclohexanone using pyridinium chlorochromate as an oxidizing agent. (iii) in the third step, 3-pentadecyl cyclohexanone was converted to (z)-1-(methoxy methylene)-3-pentadecyl cyclohexane using suspension of methoxy methyl triphenyl phosphonium in dioxane and potassium t-butoxide as a base. Finally, in step (iv) (z)-1-(methoxy methylene)-3-pentadecyl cyclohexane was converted to 3-PDCAL in the presence of p-toluene sulfonic acid using dioxane water mixture as a solvent. The reaction pathway is shown in **Scheme 3.2**.

![Scheme 3.2. Synthesis of 3-pentadecyl cyclohexane carbaldehyde](image)

FT-IR spectrum of 3-PDCAL (Figure 3.9) showed carbonyl of the aldehyde group ($>\text{C}=\text{O}$, $\text{-CHO}$ stretching vibrations) attached to the cyclohexyl ring at 1723 cm$^{-1}$. 

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$^1$H NMR spectrum of 3-PDCAL (Figure 3.10) showed terminal methyl (−CH$_3$) protons of the pentadecyl chain at 0.84 ppm (triplet, 3H, −CH$_3$), methylene (−CH$_2$) protons of the pentadecyl chain, the cyclohexyl ring and the methine proton attached to the carbon to which the pentadecyl chain is attached appeared in the range of 1.22 - 2.43 ppm (multiplet, 41 H), aldehyde proton (O=C−H) (singlet of singlet, 1H) attached to the cyclohexyl ring appeared at 9.56 ppm and 9.66 ppm which can be attributed to the axial and equatorial flipping of the cyclohexyl ring, respectively.
Figure 3.10. $^1$H NMR spectrum of 3-pentadecyl cyclohexane carbaldehyde

$^{13}$C NMR spectrum of 3-PDCAL (Figure 3.11) showed terminal methyl carbon ($-\text{CH}_3, \text{C}_1$) of the pentadecyl side chain attached to the cyclohexyl ring appeared at 14.13 ppm. Methylene ($-\text{CH}_2$) carbons of the pentadecyl chain, the cyclohexyl ring and the methine carbons ($-\text{CH}-\text{CHO}, \text{C}_{2-20}$) of the cyclohexyl ring appeared in the range of at 22.7 - 48.25 ppm. The aldehyde carbon (O=\text{C}—\text{H}, \text{C}_{21}) attached to the cyclohexyl ring appeared at 212.75 ppm.
The analysis of FT-IR spectrum and the assignment of peaks in both $^1$H and $^{13}$C spectra confirmed the structure of 3-PDCAL.

### 3.7.3 Synthesis of hydrophobic compounds from gallic acid: [MGC$_8$ and MGC$_{12}$]

Synthesis of MGC$_8$ and MGC$_{12}$ from gallic acid is shown in Scheme 3.3. In order to prevent any side reaction from the –COOH groups of gallic acid, it was first converted to methyl gallate using thionyl chloride and methanol. Methyl gallate was then converted to alkoxy substituted methyl gallate derivatives (MGC$_8$/MGC$_{12}$) by Williamson ether synthesis using alkyl bromide (C$_8$H$_{17}$Br/C$_{12}$H$_{25}$Br). Tetrabutyl ammonium bromide (TBAB) was used as a phase transfer catalyst and K$_2$CO$_3$ was used as a base.
Scheme 3.3. Preparation of methyl 3, 4, 5-tris octyloxy benzoate

FT-IR spectrum of methyl 3, 4, 5-tris (octyloxy benzoate) (Figure 3.12) showed ester carbonyl attached to the benzene ring of MGC₈ at 1727 cm⁻¹. The C-O bond of the ester appeared at 1017 - 1334 cm⁻¹. Out of plane −C–H bend of the aromatic ring appeared at 760 cm⁻¹.

Figure 3.12. FT-IR spectrum of methyl 3, 4, 5-tris octyloxy benzoate

¹H NMR spectrum of methyl 3, 4, 5-trisoctyloxy benzoate [MGC₈] (Figure 3.13) showed the terminal methyl protons of the octyl side chain, [(-CH₂)₇–CH₃], attached to the aromatic ring at 0.87 ppm (t, –CH₃, 9H). Methylene protons [(-CH₂)₅–CH₃] of the octyl side chain appeared at 1.27 – 1.80 ppm (m, –CH₂, 36H). Methyl protons of the ester group attached to aromatic ring appeared at 3.87 ppm (s, –COOCH₃, 3H). Methylene
protons of the octyl side chain [(–CH2)5–CH3] attached to the oxygen of the aromatic ring appeared at 4 ppm (t, –OCH2, 6H) and the aromatic protons appeared at 7.2 ppm (s, 2H, Ar–H).

![NMR spectrum of methyl 3, 4, 5-tris octyloxy benzoate](image)

**Figure 3.13.** $^1$H NMR spectrum of methyl 3, 4, 5-tris octyloxy benzoate

$^{13}$C NMR spectrum of MGC8 (Figure 3.14) showed the methyl carbons of the methyl gallate ester at 52.04 ppm (C1, –COOCH3). Carbonyl carbons of the methyl ester appeared at 166.91 ppm (C2, O=C–OCH3). Carbon of the aromatic ring to which methyl ester group is attached appeared at 124.66 ppm. (C3, –C–Ar) Aromatic carbons ortho with respect to methyl ester (C4,8, –C–Ar) appeared at 108.02 ppm. Aromatic meta carbons with respect to methyl ester (C5,7, –C–Ar) appeared at 152.83 ppm. Aromatic carbons para with respect to methyl ester (C6, –C–Ar) appeared at 142.41 ppm. C9 carbons appeared at of 69.16 ppm (–OCH2, 3C). C10-15 carbons appeared in the range of 22.65 – 31.82 ppm (–OCH2, 6C). C16 methyl carbon of the aliphatic side chain appeared at 14.06 ppm. (C16, –CH3, 1C)
The analysis of FT-IR spectrum and the assignments of the peaks in both $^1$H and $^{13}$C spectra confirmed the structure of MGC$_8$.

3.7.4 Methyl 3, 4, 5 tris-octyloxy benzoate [MGC$_{12}$]:

In order to increase the hydrophobicity, methyl gallate with C$_{12}$ alkyl chain (MGC$_{12}$) was synthesized using the same procedure of MGC$_8$ synthesis. During the reaction, octyl bromide was replaced by dodecyl bromide. The reaction pathway is shown in Scheme 3.4.

Scheme 3.4. Preparation of methyl 3, 4, 5-tris n-dodecyloxy benzoate
FT-IR spectrum of methyl 3, 4, 5-tris (dodecyloxy benzoate) (Figure 3.15) showed aliphatic side chain attached to aromatic ring through ether linkage at 2850-2917 cm\(^{-1}\). Ester carbonyl attached to the benzene ring of MGC\(_{12}\) appeared at 1723 cm\(^{-1}\). The carbon-carbon double bond (C\(==\)C) of the aromatic ring stretch appeared at 1583 cm\(^{-1}\). The C–O bond of the ester appeared at 1015 - 1335 cm\(^{-1}\). Out of plane C–H bend of the aromatic ring appeared at 761 cm\(^{-1}\).

Figure 3.15. FT-IR spectrum of methyl 3, 4, 5-tris dodecyloxy benzoate

\(^1\)H NMR spectrum of methyl 3, 4, 5-trisdodecyloxy benzoate (Figure 3.16) showed terminal methyl protons of the dodecyl side chain [CH\(_3\) (–CH\(_2\))\(_7\)] attached to the aromatic ring at 0.87 ppm (t, –CH\(_3\), 9 H). Methylene protons [(–CH\(_2\))\(_3\)–CH\(_3\)] of the dodecyl side chain attached to the aromatic ring appeared at 1.25 – 1.78 ppm (m, –CH\(_2\), 60 H). Methyl protons of the ester group attached to aromatic ring appeared at 3.88 ppm (s, –COOCH\(_3\), 3H). Methylene protons of the dodecyl side chain [(–CH\(_2\))\(_{10}\)–CH\(_3\)] attached to the oxygen of the aromatic ring appeared at 4.0 ppm (t, –OCH\(_2\), 6H). Aromatic protons of MGC\(_{12}\) appeared at 7.24 ppm (s, 2H, Ar–H).
Figure 3.16. \(^1\)H NMR spectrum of methyl 3, 4, 5-tris dodecylxy benzoate

\(^{13}\)C NMR spectrum of MGC\(_{12}\) (Figure 3.17) showed the methyl carbons of the methyl gallate ester at 52.11 ppm (C\(_1\), −COOCH\(_3\)). Carbonyl carbons of the methyl ester appeared at 166.98 ppm (C\(_2\), O=\text{C}\−\text{OCH}_3\). Carbon of the aromatic ring to which methyl ester group is attached appeared at 124.66 ppm. (C\(_3\), −C−Ar) Aromatic carbons ortho with respect to methyl ester (C\(_{4,8}\), −C−Ar) appeared at 108 ppm. Aromatic carbons meta with respect to methyl ester (C\(_{5,7}\), −C−Ar) appeared at 152.84 ppm. Aromatic carbons para with respect to methyl ester (C\(_6\), −C−Ar) appeared at 142.39 ppm. C\(_9\) carbons appeared at 69.19 ppm (−OCH\(_2\), 3C). C\(_{10-15}\) carbons appeared in the range of 22.71 – 31.94 ppm (−OCH\(_2\), 6C). C\(_{16}\) terminal carbon of the aliphatic side chain appeared at 14.12 ppm. (C\(_{16}\), −CH\(_3\), 1C)
Figure 3.17. $^{13}$C NMR spectrum of methyl 3, 4, 5-tris (dodecyloxy) benzoate

The analysis of FT-IR spectrum and the assignments of the peaks in both $^1$H and $^{13}$C spectra confirmed the structure of MGC$_{12}$.

3.8 Conclusion:

Hydrophobic compounds from natural resource materials such as cashew nut-shell liquid and gallic acid were prepared. Starting from 3-pentadecyl phenol two hydrophobic derivatives namely, 3-pentadecyl cyclohexyl amine and 3-pentadecyl cyclohexane carbaldehyde were prepared. From gallic acid, two hydrophobic derivatives were prepared namely, methyl tris-octyloxy benzoate and methyl tris-dodecyloxy benzoate. The structural elucidation of all the hydrophobic compounds were performed using IR and NMR spectroscopy. The hydrophobic compounds were later used in synthesizing HMPs which are given in the subsequent chapters.
References:


23. Bate-Smith and Swain “Flavonoid compounds: Comparative Biochemistry,”
25. Singh, O. V.; Steven, H. P. “Sustainable Biotechnology: Sources of Renewable