Chapter Three

Aldol type Condensation Reactions of Acyl Ketene Dithioacetals

3.1 Introduction

\( \alpha' \)-Deprotonation of acyl ketene dithioacetals with strong bases and the addition of the resultant enolate anions to aromatic aldehydes provide easy access to cinnamoyl ketene dithioacetals.\(^1\) The cinnamoyl ketene dithioacetals and other alkenoyl ketene dithioacetals are valuable synthetic intermediates. Junjappa and co-workers have developed several acid catalyzed methods for the cyclization of these intermediates to cyclopentanoids. Selective conversion of the double bond in the alkenoyl group to cyclopropane or oxirane provide highly functionalized ketene dithioacetals, which also have found application in the synthesis of cyclopentanoids and substituted heterocycles.\(^5\)\(^6\)

Application of the carbonyl group transposition methodology on alkenoyl ketene dithioacetals or vinyl sulfides leads to the formation of polyene esters or aldehydes respectively. The reactions involving \( \alpha' \)-deprotonation of \( \alpha \)-oxo ketene dithioacetals and synthetic applications of the resultant intermediates are presented in Chapter two. On this background we have attempted the \( \alpha' \)-deprotonation of diacetyl ketene dithioacetals and the addition of the resultant enolate to aromatic aldehydes to afford bis alkenoyl ketene dithioacetals.
3.2 Results and Discussion

α-Oxo ketene dithioacetals are usually prepared by the deprotonation of active methylene ketones with a suitable base followed by addition to carbon disulfide and subsequent alkylation with an alkylating agent. Sandstrom and Wennerbeck have prepared the ketene dithioacetal of 2,4-pentanedione and several other ketones using sodium hydride as the base in a mixture of benzene and DMF (Scheme 1).

More recently several modifications were reported for the preparation of diacetyl ketene dithioacetal, and acyl ketene dithioacetals in general. For instance Villemin and Alloum have used potassium fluoride supported on alumina for a facile synthesis of ketene dithioacetals by the condensation of carbon disulfide and active methylene compounds with subsequent alkylation. El-Shafei and co-workers reported that the mild base, potassium carbonate in the presence of phase transfer catalyst such as tetrabutylammonium bromide in benzene as solvent is good enough for the condensation of acetyl acetone with carbon disulfide. This on subsequent alkylation with methyl iodide gave the corresponding diacetyl ketene dithioacetal in quantitative yield.
Acyl ketene dithioacetals can also be prepared under acidic conditions. Gompper and co-workers have described the reactions of naphthols, phenols and some enolizable carbonyl compounds with trithiocarbenium salts. Thus the reaction of acetyl acetone with trithiocarbenium salt 4 in acetic acid in the presence of pyridine afford the diacetyl ketene dithioacetal 5 in 45% yield\(^\text{10}\) (Scheme 2).

\[
\begin{align*}
\text{H}_3\text{C} & \quad \text{CH}_3 \\
\text{O} & \quad \text{O} \\
\end{align*}
\]

\[
\begin{align*}
\text{S} & \quad \text{CH}_3\text{SO}_4^{-} \\
\text{S} & \quad \text{SCH}_3 \\
\end{align*}
\]

\[
\begin{align*}
\text{H}_3\text{C} & \quad \text{CH}_3 \\
\text{O} & \quad \text{O} \\
\end{align*}
\]

\[
\text{Scheme 2}
\]

For the preparation of diacetyl ketene dithioacetal having bis(methylthio) methylene functionality we have employed the method reported by Sandstrom and Wennerbeack. However for the synthesis of 3-(1,3-dithiolan-2-ylidene)-2,4-pentanedione we have used potassium hydroxide pellets as the base and acetonitrile as the solvent. After condensation with carbon disulfide subsequent alkylation was carried out with 1,2-dibromoethane. Simple filtration and washing with dilute acid gave excellent yield of the cyclic ketene dithioacetal 5.

Condensation reactions of acyl ketene dithioacetals with aromatic aldehydes are usually done in ethanol or methanol using respective sodium alkoxide or sodium hydroxide as the base.\(^{1-4}\) We have also attempted the condensation of diacetyl ketene dithioacetals with aromatic aldehydes under similar conditions.

3.2.1 The reactions of 3-[bis(methylthio)methylene]pentane-2,4-dione with substituted benzaldehydes.

The ketene dithioacetal 3 derived from 2,4-pentanedione was allowed to react with benzaldehyde in the presence of sodium ethoxide in ethanol. The reaction mixture was stirred at 0-5°C for four hours. The TLC examination of the mixture has shown complete disappearance of the starting ketene dithioacetal. An yellow solid was separated which
was filtered and washed with ethanol. The yellow solid thus obtained was further purified by recrystallization from a mixture of hexane and ethyl acetate. The recrystallized solid had a mp 136-137°C. Based on the spectral data this product was identified to be 1,7-bis(phenyl)-1,6-heptadiene-3,5-dione 7a.

The proton NMR spectrum (250 MHz, CDCl₃, Fig1) of 7a indicates that the compound exists in a completely enolized form. The vinylic proton between the carbonyl and the hydroxy group was found as a singlet at δ 5.86 ppm. The two doublets, one at δ 6.65 ppm (2H, J=15 Hz) and the other at δ 7.70 ppm (2H, J=15Hz) were attributed to the other vinylic protons. The fact that these four vinylic protons exhibit just two doublets indicates a symmetric structure for the compound. The ten aromatic protons appeared as multiplets between δ 7.27 and 7.65 ppm (Scheme 3).

\[ \text{R} - \text{CHO} + \begin{array}{c}
\text{CH}_3 \\
\text{CH}_3S \\
\text{SCH}_3
\end{array} \rightarrow \begin{array}{c}
\text{R} \\
\text{R}
\end{array} \]

\[ \text{NaOH/PROH} \]

\[ 6,7 \begin{array}{a}
a. \text{R}=\text{H} \\
b. \text{R}=	ext{Cl} \\
c. \text{R}=\text{p-OCH}_3
\end{array} \]

Scheme 3

The Carbon-13 NMR spectra (62.9 MHz, CDCl₃, Fig 2) of 7a showed the signal due to methylene group at δ 101.81 ppm. The peak at δ 124.09 ppm was due to C-2 and C-6, while the peak due to C-1 and C-7 appeared at δ 140.64 ppm. The peak due to the
Fig. 1 $^1$H NMR Spectrum (250 MHz) of compound 7a
Fig. 2 $^{13}$C NMR Spectrum (62.9 MHz) of compound 7a
carbonyl group appeared at δ 183.33 ppm while the peaks at δ 128.13, 128.94, 130.12 and 135.00 ppm were due to the carbons in the aromatic rings.

The mass spectrum (EIMS, Fig 3) showed the molecular ion peak at m/z 278. The base peak was at m/z 131, which was attributed to (Ph-CH=CH-C=O)\textsuperscript{+}. Other prominent peaks were at m/z 103 (Ph-CH=CH\textsuperscript{+} and 77 (Ph\textsuperscript{+}).

The IR spectrum of the compound 7a (KBr, Fig 4) showed a low stretching frequency for the carbonyl group at \(v=1620\) cm\(^{-1}\) apparently due to the high contribution of the enolic form. The enolic OH stretching was found at \(v=3400\) cm\(^{-1}\) while a sharp band at \(v=1140\) cm\(^{-1}\) may be attributed for C-O stretching due to the enolic group.

The 1,7-bis(phenyl)-1,6-heptadiene-3,5-dione 7a is analogue of natural curcumin 8

![Curcumin](image)

Curcumin 8 isolated from turmeric (curcuma longa) is a well known natural antioxidant. Curcumin and its analogues have been reported to show cytotoxic\textsuperscript{11} and anticancer properties.\textsuperscript{12-14} They are also potential photodynamic agents for the destruction of bacteria and tumor cells.\textsuperscript{15,16}

The direct condensation of acetyl acetone with substituted benzaldehydes under certain conditions are known to give useful yields of curcumin and its derivatives. Pabon has reported a synthesis of curcumin and several analogues of curcumin, by the condensation of vanillin and other substituted benzaldehydes with a complex formed from acetyl acetone and boric anhydride in the presence of tributyl borate and butyl amine.\textsuperscript{17} Rajasekharan and Dinesh Babu have recently optimized the reaction conditions for the synthesis of curcumin analogues. They found that the reaction of acetyl acetone with aromatic aldehydes proceed smoothly in the presence of borate and amine acetate.\textsuperscript{18} Another report on the synthesis of curcumin analogues employs 2, 3, 5-trimethyl
Fig. 3 Mass Spectrum (EIMS) of compound 7a
Fig. 4 IR Spectrum (KBr) of compound 7a
isoxazolium salt as the equivalent of acetyl acetone for condensation with substituted benzaldehydes.$^{19}$

To the best of our knowledge, protection of the methylene group of acetyl acetone aimed at the deprotonation of methyl groups has not been explored systematically. The bis(methylthio)methylenic functionality itself has not attracted much attention as a potential protective group.

Scheme 4
But in contrast, it is interesting to note that the closely related alkylthio ethylenic group has found wide acceptance as a protecting group for cyclic ketones. This protocol has been used successfully for carrying out regioselective alkylations on decalones \(^{20}\) (Scheme 4).

When we have attempted the aldol type condensation of the ketene dithioacetal derived from acetyl acetone, we did not anticipate the removal of the bis(methylthio)methylene functionality under the reaction conditions. On the other hand, the reaction was aimed at the synthesis of bis(cinnamoyl)ketene dithioacetals. However, we hoped that after the synthesis of bis(cinnamoyl)ketene dithioacetal, the bis(methylthio)methylene functionality can be deprotected under some conditions, thus providing an alternative method for the synthesis of curcumin analogues.

![Scheme 5](image-url)
While our work was in progress Pak and co-workers have reported a method for the synthesis of cinnamoyl ketene dithioacetals.\(^1\) The reaction involves base catalyzed condensation of the cyclic ketene dithioacetal derived from ethyl acetoacetate with ketones and aldehydes. They have proposed formation of a cyclic intermediate \(16\) resulting from the intramolecular attack of the aldol group with the ethoxy carbonyl functionality. The cinnamoyl ketene dithioacetals \(18\) are proposed to be formed by the ring opening of the cyclic intermediate \(16\) to furnish the \(1\)-(2-alkenoyl)-1-carboxy ketene dithioacetals \(17\) and subsequent removal of the carboxylic acid group by heating at high temperature (Scheme 5). The proposed cyclic compound could only be detected by TLC because the ring opening was fairly fast. It was interesting to note that the facile ring opening results from the presence of sodium ethoxide in the mixture, which was formed during the cyclization process. The authors have proved this point by the independent synthesis of the cyclic compound which was found to be stable in the presence of sodium hydride as well as \(\text{dil. HCl}\), but underwent smooth ring opening in the presence of sodium ethoxide in THF.

The removal of bis(methylthio)methylene group along with the aldol type condensation of diacetyl ketene dithioacetal also might involve similar cyclic species as intermediate. Aldol type condensation on both acyl groups may take place simultaneously to afford the aldol \(19\). Cyclization involving one of the aldol moiety and subsequent base catalyzed removal of one of the methylthio group should lead to the formation of an intermediate dihydropyrrone \(21\). The ring opening of this intermediate must be facilitated by the presence of a base. As a result of such a ring opening the thiolester \(22\) could be formed. Again another cyclization could take place, which involve the aldol and thiolester functionalities. This should lead to the formation of a lactone which is similar to the one proposed by Choi and co-workers\(^14\) while examining the aldol type condensation of the cyclic ketene dithioacetal derived from ethyl acetoacetate. The \(1,7\)-bis(phenyl)-1,6-heptadiene-3,5-dione \(7a\) could be formed by the base catalyzed ring opening of the lactone \(23\) followed by decarboxylation (Scheme 6).

We have examined the base catalyzed condensation reactions of diacetyl ketene dithioacetal \(3\) with other substituted aromatic aldehydes as well.
Scheme 6
Among substituted benzaldehydes only \( p \)-chloro benzaldehyde and anisole gave us the corresponding 1,7-bis(aryl)-1,6-heptadiene-3,5-diones 7b and 7c in 60% and 63% yields respectively. The structures of these compounds were confirmed on the basis of spectral and analytical data, which are given in the experimental section.

When similar aldol-type condensation of the ketene dithioacetal 3 derived from acetyl acetone was attempted with \( m \)-methoxy benzaldehyde the only product that could be isolated was identified to be 1,1-bis(methylthio)-5-(3-methoxyphenyl)-1,4-pentadiene-3-one 26 on the basis of spectral data.

![Scheme 7](image-url)
Though it was disappointing to obtain the \( m \)-methoxy substituted cinnamoyl ketene dithioacetal as the product (cinnamoyl ketene dithioacetals can be conveniently prepared by base catalyzed condensation of acyl ketene dithioacetals with substituted benzaldehydes) the mechanism by which this has been formed from diacetyl ketene dithioacetal was intriguing.

The formation of \( m \)-methoxy substituted cinnamoyl ketene dithioacetal 26 as a result of the condensation of 3-bis(methylthio)methylene pentane-2,4-dione 3 with \( m \)-methoxy benzaldehyde might have resulted from a deacetylation reaction assisted by the intramolecular attack of the aldol group to the acyl functionality (Scheme 7).

Cyclization involving the aldol and the acyl group may lead to the formation of a cyclic intermediate 25 which could be unstable and undergo a facile ring opening and loss of a molecule of acetic acid leading to the formation of the substituted cinnamoyl ketene dithioacetal 26. It might be also possible that, the acyl group could have undergone aldol condensation with another molecule of \( m \)-methoxy benzaldehyde, and in that case \( m \)-methoxy substituted cinnamic acid would be removed while ring opening.

We thought that by changing the reaction conditions we may find a suitable combination of reagents that would be able to perform the condensation of ketene dithioacetal derived from acetyl acetone with substituted benzaldehydes, in such a way that the simultaneous deacetylation or removal of bis(methylthio)methylene functionality would not take place. We have tried the reaction using powdered potassium hydroxide or potassium carbonate in benzene, in the presence of a phase transfer catalyst, but the results were similar to that obtained in NaOEt/EtOH. When the reaction was done in THF using sodium hydride as the base, we could obtain some products in low yields, which could not be characterized. Since we have failed in finding a mild base catalyzed reaction condition under which the deacetylation or the removal of the bis(methylthio)methylene functionality could be checked we have turned our attention to acid catalyzed conditions.
3.2.2 The reactions of 3-bis(methylthio)methylene pentane-2,4-dione with substituted benzaldehydes under acid catalyzed conditions

The ketene dithioacetal functionality is known to undergo hydrolysis in the presence of protic acids such as sulfuric acid employing methanol or tetrahydrofuran, as the solvent. As expected, the bis-alkenoyl ketene dithioacetal was not among the products formed. However a solid product (mp 94-95°C) could be obtained from the acid catalyzed reaction in methanol which could not be characterized yet.

We have next attempted the aldol condensation in the presence of Lewis acids. When the diacetyl ketene dithioacetal was treated with benzaldehyde in the presence of boron trifluoride etherate in methylene chloride the reaction did not proceed.

Some time back Harrison\textsuperscript{22} has reported that aldol condensation of active methylene compounds with various aromatic aldehydes proceeds smoothly in the presence of a combination of titanium tetrachloride and triethyl amine, in methylene chloride at 0°C. We attempted the condensation of the ketene dithioacetal derived from acetyl acetone with various aromatic aldehydes under this condition to see whether we can check the deacetylation and removal of the bis(methylthio) methylene functionality. The ketene dithioacetal 3 derived from acetyl acetone was allowed to react with benzaldehyde (10 mmol) in the presence of titanium tetrachloride (11 mmol) and triethyl amine, (11.5 mmol) in methylene chloride at 0°C for one hour. The reaction mixture after work up was column chromatographed. The orange yellow solid thus obtained had a mp 132-134°C. Based on the spectral data the product was identified to be 1,7-bis(phenyl)-4-bis(methylthio)methylene-1,6-heptadiene-3,5-dione 27 (Scheme 8).

In the proton NMR spectrum (200 MHz, CDCl\textsubscript{3}, Fig 5) the two doublets one at δ 6.97 ppm (2H, J=15 Hz) and the other at δ 7.65 ppm (2H, J=15 Hz) were due to the vinylic protons. The six SCH\textsubscript{3} protons appeared as a singlet at δ 2.45 ppm. The ten aromatic protons appeared as multiplets between δ 7.26 and 7.41 ppm.
Fig. 5 $^1$H NMR Spectrum (200 MHz) of compound 27
The Carbon-13 NMR spectrum (50.3 MHz, CDCl$_3$) of 27 (Fig 6) showed the signal due to SCH$_3$ at $\delta$ 18.76 ppm. The aromatic and vinylic carbons showed only six peaks due to the symmetry of the molecule. They are at $\delta$ 126.32, 128.75, 129.09, 130.86, 134.70, 145.21 ppm. The signal due to the carbonyl group appeared at $\delta$189.98 ppm. However the signals due to the quaternary carbons of the ketene dithioacetal moiety did not appear clearly in the spectrum. Even in the spectrum of the ketene dithioacetal obtained from acetyl acetone, the peaks due to the vinylic carbons of the ketene dithioacetal moiety could not be clearly observed (Fig 7).

The mass spectrum of the compound (EIMS, Fig 8) showed the molecular ion peak at m/z 380. The base peak at m/z 103 was attributed to [Ph-CH=CH]$^+$*. Other prominent peaks were at m/z 333 and m/z 77.

The IR spectrum (KBr, Fig 9) of the compound showed a stretching frequency for the carbonyl group at v=1628 cm$^{-1}$. Other prominent bands were at v=1580, 1460, and 1160 cm$^{-1}$.

However when similar aldol type condensations were attempted with other substituted benzaldehydes the corresponding thiolesters were obtained instead of the bis (cinnamoyl) ketene dithioacetals. The p-chlorobenzaldehyde on condensation with 3-
Fig. 6 $^{13}$C NMR Spectrum (50.3 MHz) of compound 27
Fig. 7 $^{13}$C NMR Spectrum (50.3 MHz) of compound 3
Fig. 8 Mass Spectrum (EIMS) of compound 27
Fig. 9 IR Spectrum (KBr) of compound 27
bis(methylthio)methylenepentane-2,4-dione in the presence of titanium tetrachloride and triethyl amine in methylene chloride at 0°C for one hour gave an orange yellow solid with mp 174-175°C. Based on the spectral data the compound was identified to be 28 (Scheme 9).

\[
\text{R} = \text{Cl, OCH}_3
\]

Scheme 9

The proton NMR spectrum (200 MHz, CDCl\textsubscript{3}, Fig 10) showed a singlet at δ 2.6 ppm (3H) due to SCH\textsubscript{3} protons. The two doublets at δ 6.9 ppm (2H, J=15 Hz) and δ 7.7 ppm (2H, J=15 Hz) were due to the vinylic protons. The eight aromatic protons appeared as multiplets between δ 7.2 and 7.5 ppm. The proton α-to the thiolester group could not be observed in the proton NMR spectrum.

The Carbon-13 NMR spectrum (50.3 MHz, CDCl\textsubscript{3}) of 28 (Fig 11) showed a signal at δ 13.73 ppm due to SCH\textsubscript{3} carbon. The aromatic and vinylic carbons showed peaks at δ 121.24, 129.24, 129.70, 133.25, 136.59 and 141.76 ppm. The signals due to the three carbonyl groups appeared at δ 180.00, 182.13 and 183.92 ppm.

The mass spectrum of the compound (EI MS, Fig 12) showed the molecular ion peak at m/z 418. The base peak was at m/z 165 which was attributed to [Cl-Ar-CH=CH-C-O]\textsuperscript{+}. Other prominent peaks were at m/z 371, 137 and 102.
Fig. 10 $^1$H NMR Spectrum (200 MHz) of compound 28
Fig. 11 $^{13}$C NMR Spectrum (50.3 MHz) of compound 28
Fig. 12 Mass Spectrum (EIMS) of compound 28
The IR spectrum (KBr, Fig 13) of the compound showed the stretching frequency due to the carbonyl group at $\nu = 1620 \text{ cm}^{-1}$. Other prominent bands were at $\nu = 1480, 1420$ and $1080 \text{ cm}^{-1}$.

The $p$-methoxybenzaldehyde on similar reaction gave the corresponding thiolester just as in the case of $p$-chlorobenzaldehyde. The spectral data of the compound is given in the experimental section.

The aldol type condensation of the ketene dithioacetals derived from acetyl acetone, having bis(methylthio)methylene functionality, almost always proceeded with either complete removal of the ketene dithioacetal moiety or partial hydrolysis of the bis(methylthio)methylene group to the thiol ester group. Though the curcumin derivatives and their thiol esters are important compounds as such, due to their possible biological properties, we were particularly interested in bis(alkenoyl) ketene dithioacetals and their subsequent applications in synthetic transformations. Since our efforts directed towards the synthesis of bis(alkenoyl) ketene dithioacetals starting from the ketene dithioacetal 3, derived from acetyl acetone, having methylthio substituents, we have turned our attention to the reaction involving the ketene dithioacetal 5, where the cyclic ketene dithioacetal moiety is expected to be more resistant towards hydrolysis.

3.2.3 The reaction of 3-(1,3-dithiolan-2-ylidene)-2,4-pentanedione with aromatic aldehydes.

The cyclic ketene dithioacetal 3-(1,3-dithiolan-2-ylidene)-2,4-pentanedione 5 was obtained in 78% yield, by the base catalyzed reaction of acetyl acetone with carbon disulfide followed by alkylation with dibromoethane. Potassium hydroxide was the base used and the reaction was carried out in acetonitrile.

The ketene dithioacetal 5 was then allowed to react with benzaldehyde in the presence of sodium ethoxide in ethanol. The reaction mixture was stirred at 0-5°C for four hours. A yellow solid was separated which was filtered and washed with ethanol. It was further purified by recrystallization from a mixture of hexane and ethyl acetate. The solid obtained had a mp 157-158°C. The product was identified to be 1,7-bis(phenyl)-4-
Fig. 13 IR Spectrum (KBr) of compound 28
(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 29a based on the spectral data (Scheme 10).

In the proton NMR spectrum (250 MHz, CDCl₃, Fig 14) a singlet of four hydrogen at δ 3.4 ppm was due to the SCH₂ protons. The spectrum also showed two doublets one at δ 6.9 ppm (2H, J=15 Hz) and the other at δ 7.7 ppm (2H, J=15 Hz) due to the vinylic protons. The ten aromatic protons appeared as multiplets between δ 7.4 and 7.6 ppm.

The Carbon-13 NMR spectrum (CDCl₃, 62.9 MHz) of 29a (Fig 15) showed the signal due to SCH₂ at δ 37.32 ppm. The signals at δ 125.92 and 143.77 ppm were due to the vinylic carbons. The aromatic carbons showed signals at δ 127.90, 128.41, 128.93, 130.51 and at 134.75 ppm. The signal due to carbonyl carbon appeared at δ 187.80 ppm.
Fig. 14 ¹H NMR Spectrum (250 MHz) of compound 29a
Fig. 15 $^{13}$C NMR Spectrum (62.9 MHz) of compound 29a
The mass spectrum of the compound (EIMS, Fig 16) showed the molecular ion peak at m/z 378. The base peak was at m/z 103 which was due to the fragment [Ph-CH=CH]'. The other prominent peaks were at m/z 131, 99 and 77.

The IR spectrum (KBr, Fig 17) of the compound showed the stretching frequency due to the carbonyl group at ν=1620 cm\(^{-1}\). Other prominent bands were at ν=1580, 1380, 1330, 1280, 1220, 1160, 1040 cm\(^{-1}\).

Similarly other substituted benzaldehydes such as p-methoxybenzaldehyde, p-chlorobenzaldehyde, m-methoxybenzaldehyde and 3,4-dimethoxybenzaldehyde also gave the corresponding 1,7-bis(aryl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 30b-e on condensation with 3-(1,3-dithiolan-2-ylidene)-2,4-pentanedione in the presence of sodium ethoxide in ethanol (Scheme 10). The structures of the bis(alkenoyl) ketene dithioacetals 30b-e were confirmed with the help of proton NMR, Carbon-13 NMR, mass spectra and IR spectra. The spectral data of these compounds are given in the experimental section.

When furfuraldehyde was condensed with 3-(1,3-dithiolan-2-ylidene)-2,4-pentanedione in the presence of sodium ethoxide in ethanol an yellow solid was obtained. The recrystallized solid had a mp 128-129°C. Based on the spectral data the compound was identified to be 1,7-bis(furyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 31a (Scheme 11).

The proton NMR spectrum (90 MHz, CDCl3, Fig 18) showed a singlet (4H) at δ3.4 ppm due to SCH\(_2\) protons. The peaks between δ 6.4 and 7.7 ppm were due to the vinylic and aromatic protons.

The mass spectrum (EIMS, Fig 19) showed the molecular ion peak at m/z 358. Other prominent peaks were at m/z 290, 175, 121, 103, 77.

The IR spectrum (KBr, Fig 20) showed the stretching due to the carbonyl group at ν=1620 cm\(^{-1}\). The other prominent bands were at ν=1580, 1540 and 1420 cm\(^{-1}\).
Fig. 16 Mass Spectrum (EIMS) of compound 29a
Fig. 17  IR Spectrum (KBr) of compound 29a
Fig. 18 $^1$H NMR Spectrum (90 MHz) of compound 31a
Fig. 19 Mass Spectrum (EIMS) of compound 31a
Fig. 20  IR Spectrum (KBr) of compound 31a
The thiophene-2-carboxaldehyde also gave the corresponding bis(thienyl) ketene dithioacetal 31b on condensation with 3-(1,3-dithiolan-2-ylidene)-2,4-pentanedione in the presence of sodium ethoxide in ethanol (Scheme 11). The spectral data of the product was consistent with the proposed structure and is given in the experimental section.

Thus we could conveniently prepare a variety of substituted bis(alkenoyl) ketene dithioacetals starting from the cyclic acyl ketene dithioacetal 5 and substituted benzaldehydes and other aromatic aldehydes. We did not isolate any product involving deacetylation or removal of the ketene dithioacetal functionality. The bis(cinnamoyl) ketene dithioacetal 29 was subjected to Lewis acid or protic acid catalyzed solvolytic conditions. But the cyclic ketene dithioacetal moiety was found to be stable towards acid catalyzed solvolysis.
3.2.4 Reaction of 2-(1,3-dithiolan-2-ylidene)-1-phenyl-1,3-butanedione with aromatic aldehydes

We have next examined some reactions involving the ketene dithioacetal obtained from benzoyl acetone. Thus when 2-(1,3-dithiolan-2-ylidene)-1-phenyl-1,3-butanedione 32 was allowed to react with benzaldehyde in the presence of sodium ethoxide in ethanol an yellow crystalline solid product was obtained. The product obtained had a mp 176-177°C. Based on the spectral data the product was identified to be 1,5-bis(phenyl)-2-(1,3-dithiolan-2-ylidene)-4-pentene-1,3-dione 33 (Scheme 12).

The proton NMR spectrum (90 MHz, CDCl₃, Fig 21) showed a singlet of four hydrogen at δ 3.35 ppm due to the SCH₂ protons. The doublet at δ 6.4 ppm (J=15Hz) was due to the vinylic proton. The multiplet of eleven hydrogen at δ 7.1-7.9 ppm was due to the vinylic and aromatic protons.
Fig. 21 $^1$H NMR Spectrum (90 MHz) of compound 33a
The mass spectrum (EIMS, Fig 22) gave the molecular ion peak at m/z 352. Other prominent peaks were at m/z 264, 236, 105, 77.

The IR spectrum (KBr, Fig 23) gave prominent peaks at ν=1610, 1580, 1420, 1200 cm⁻¹.

The ketene dithioacetal 32 also underwent condensation with p-methoxy benzaldehyde in a similar fashion (Scheme 12). The spectral data of the product 33b obtained is given in the experimental section.

Though we have anticipated a debenzoylation reaction involving the intermediate β-hydroxy ketone, the reaction did not give any products resulting from debenzoylation.

3.2.5. Reaction of 1,7-bis(phenyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione with sulfoxonium methylide

The cyclopropyl ketones, prepared from cinnamoyl ketene dithioacetals on treatment with dimethyl sulfoxonium ylides, are important substrates for the synthesis of cyclopentanoids. The cyclization could be achieved either in the presence of a mixture of formic acid and phosphoric acid or by treatment with SnCl₄ in benzene. The reaction in H₃PO₄/HCO₂H results in either complete or partial removal of bis (methylthio)methylene functionality. But in the presence of SnCl₄ the ketene dithioacetal functionality remained intact.²⁴,²⁵ One example involving the SnCl₄ asisted cyclization is shown in scheme 13.

We have anticipated that the cyclopropyl ketones, that could be synthesized from bis-alkenoyl ketene dithioacetals, would also undergo valuable transformations. Cyclopropanation could be carried out efficiently on both the cinnamoyl functionalities.

Thus when 1,7-bis(phenyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 29a was allowed to react with sulfoxonium methylide under phase transfer catalyzed condition the cyclopropanation took place at the styryl double bond to afford the cyclopropyl ketone 37 (Scheme 14).
Fig. 22 Mass Spectrum (EIMS) of compound 33a
Fig. 23  IR Spectrum (KBr) of compound 33a
Scheme 13

Scheme 14
The proton NMR spectrum (200 MHz, CDCl₃, Fig 24) showed a singlet of four hydrogen at δ 3.3 ppm due to SCH₂ protons. It showed a multiplet of ten hydrogen at δ 6.7-7.25 ppm due to the aromatic protons. The multiplets at δ 1.10-1.24, 1.45-1.56 and 1.78-1.91 ppm were due to methylene protons of the cyclopropyl ring on either side of the molecule. The multiplets at δ 2.40-2.51, 2.55-2.68 and 2.75-2.89 ppm were due to methine protons of the cyclopropyl ring.

The ¹³C-NMR spectrum (50.3 MHz, CDCl₃) (Fig 25) showed the signals due to SCH₂ carbons at δ 37.14 and 36.99 ppm. The peaks at δ 20.39 and 20.90 ppm were due to the methylenic carbons of the cyclopropyl ring. The signals at δ 30.46, 30.91, 33.31 and 35.17 ppm were due to methine carbons of the cyclopropyl ring. The aromatic carbons gave signals at δ 125.64, 126.08, 126.51, 128.43 and 128.49 ppm. The signals at δ 139.96 and 140.15 ppm were due to the quaternary carbons. The signals due to the carbonyl carbons appeared at δ195.57 and 196.10 ppm.

The mass spectrum (EIMS, Fig 26) showed the molecular ion peak at m/z 406. Other prominent peaks were at m/z 302, 245, 184, 145, 115, 91, 39.

The IR-spectrum showed (KBr, Fig 27) the prominent bands at ν=1600, 1410, 1220 cm⁻¹.

The proton NMR and C-13 NMR spectra indicate that the compound do not have a symmetric structure.

3.2.6. Reaction of 1,7-bis(phenyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione with sulfoxonium methylide

Aldol type condensation of acyl ketene dithioacetals with aromatic aldehydes leads to cinnamoyl ketene dithioacetals which undergo a variety of useful synthetic transformations. But corresponding aliphatic compounds could not be prepared by direct condensation owing to self condensation of the aldehyde. An alternative route for this was developed employing enaminketone derived from ketene dithioacetal.²⁶ The chemoselective 1,4-addition of alkyl Grignard reagents on enamine moiety leads to
Fig. 24 $^1$H NMR Spectrum (200 MHz) of compound 37
Fig. 25 $^{13}$C NMR Spectrum (50.3 MHz) of compound 37
Fig. 26 Mass Spectrum (EIMS) of compound 37
Fig. 27 IR Spectrum (KBr) of compound 37
aliphatic analogues of cinnamoyl ketene dithioacetals. The enaminones obtained from 3-(1,3-dithiolan-2-ylidene)-2,4-pentanedione can also undergo similar transformations.

When 3-(1,3-dithiolan-2-ylidene)-2,4-pentanedione was condensed with dimethylformamide diethyl acetal at 110°C a red solid with mp 105-107°C was isolated. The product was identified to be 1,7-bis(N,N-dimethylamino)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 39 based on the spectral data (Scheme 15).

![Scheme 15](image)

The proton NMR spectrum (90 MHz, CDCl3) showed a singlet of four hydrogen at δ 3.2 ppm due to SCH2 protons. A singlet of twelve hydrogen at δ 2.2 ppm was due to NCH3 protons. The two doublets one at δ 5.2 ppm (J=12 Hz) and the other at δ 7.6 ppm (J=12 Hz) were due to the vinylic protons.

The IR spectrum (KBr) showed prominent peaks at ν=1620, 1570, 1480, 1340, 1270, and 1220 cm⁻¹.

### 3.2.7 Cycloaddition reactions of bis(cinnamoyl) ketene dithioacetal

We have also attempted some cycloaddition reactions of bis (cinnamoyl) ketene dithioacetal 29a in the presence of Lawessons reagent (Scheme 16). It was expected that on the conversion of carbonyl group to thiocarbonyl group, the intermediate heterodiene could be trapped by electron deficient dienophiles.
The reaction was carried out with the ketene dithioacetal 29a and maleic anhydride. A mixture in toluene was refluxed in the presence of Lawesson’s reagent for eight hours. The reaction mixture was filtered, the filtrate was evaporated and the residue was chromatographed over silicagel. A solid crystalline product was isolated in 58% yield.

The NMR spectrum of the compound (300 MHz, CDCl₃, Fig 28) showed very complex multiplets due to methylene protons. The Carbon-13 NMR (22.3 MHz, CDCl₃, Fig 29) showed the presence of two carbonyl groups probably due to the anhydride moiety. The FABMS (Fig 30) showed the base peak at m/z 429 indicating that the molecular weight could be 429. IR spectrum (KBr, Fig 31) showed bands at ν=3450, 1660, 1530, 1260, 1140, 760, 700 cm⁻¹. A correct structure to this compound is yet to be assigned.

3.3 Conclusions

A variety of aromatic aldehydes were subjected to aldol type condensation with various diacetyl ketene dithioacetals under acid and base catalyzed conditions aiming at the formation of corresponding bis(cinnamoyl) ketene dithioacetals. The condensation of diacetyl ketene dithioacetal of acetyl acetone under base catalyzed conditions gave curcumin analogues instead of the expected bis(cinnamoyl) ketene dithioacetal. The methoxy substituted aldehydes gave corresponding cinnamoyl ketene dithioacetals. A mechanism have been proposed to account for the formation of curcumin analogues and cinnamoyl ketene dithioacetals. The cyclic diacetyl ketene dithioacetals on condensation
Fig. 28  $^1$H NMR Spectrum (300 MHz) of 40
Fig. 29 $^{13}$C NMR Spectrum (22.3 MHz) of 40
Fig. 30 FABMS of compound 40
Fig.31 IR Spectrum (KBr) of compound 40
gave the expected bis(cinnamoyl) ketene dithioacetals. The deprotection of the cyclic moiety of the cinnamoyl ketene dithioacetals obtained proved to be rather difficult. A convenient method developed for its deprotection would lead to a novel route for the synthesis of curcumin analogues. The bis(cinnamoyl) ketene dithioacetals have been shown to undergo smooth conjugate cyclopropanation. The products obtained from the cycloaddition reactions of bis(cinnamoyl) ketene dithioacetals in the presence of Lawesson's could not be identified.

3.4 Experimental

Melting points are uncorrected and were obtained on a Buchi-530 melting point apparatus. Infrared spectra were measured with a Shimadzu IR-470 spectrometer and are given as cm\(^{-1}\). Proton NMR spectra were recorded on a varian 390 (90 MHz), Bruker WM 250 (250 MHz), or on a Bruker WM 200 (200 MHz) spectrometer in CDCl\(_3\). Carbon-13 NMR spectra were recorded on a Bruker WM 250 (62.9 MHz) or on a Bruker WM 200 (50.8 MHz) spectrometer in CDCl\(_3\). Chemical shifts are reported in parts per million (ppm) downfield from internal tetra methyl silane. Coupling constants \(J\) are given in Hz. Electron impact mass spectra were obtained on a Finnigen-Mat 312 instrument.

3.4.1 Preparation of 3-[bis(methylthio)methylene]pentane-2,4-dione. (3)

To a suspension of NaH (2.4 g, 0.1 mol) in DMF (50 mL) and Benzene (50 mL) a mixture of acetyl acetone (10 mL, 0.1 mol) and carbon disulfide (6.5 ml, 0.1 mol) was added and stirred at room temperature for two hours. A solution of methyl iodide (13 mL, 2 mol) in benzene (10 mL) was added to this and the reaction mixture was stirred for another 24 hours. It was then diluted with benzene and washed with water dried and evaporated in vacum. The crude solid obtained was recrystallized from a mixture (1:1) of petroleum ether and benzene. mp 61°C (lit.mp 61°C). 7
3.4.2 The reactions of 3-[bis(methylthio)methylene]pentane-2,4-dione with substituted benzaldehydes.

General procedure
Sodium metal (0.46 g, 20 mmol) was dissolved in ethanol (20 mL) to which the diacetyl ketene dithioacetal (1.02 g, 5 mmol) in ethanol (10 mL) was added followed by the substituted benzaldehyde (10 mmol). The reaction mixture was stirred at 0-5°C for 4 hours. The solid separated was filtered and recrystallized from a mixture of hexane and ethylacetate.

1,7-bis(phenyl)-1,6-heptadiene-3,5-dione 7a
Obtained as yellow crystalline solid. Yield (0.90 g, 65%), mp 136-137°C (lit mp 140°C). IR ν<sub>max</sub>/cm<sup>-1</sup> 1620 (C=O), 1580 (C=C), 3400 (enolic OH), 1140 (enolic C-O).<sup>1</sup>H NMR (250 MHz, CDCl<sub>3</sub>) δ 5.86 (1H, s, vinylic), 6.65 (2H, d, J=15 Hz, vinylic), 7.27-7.65 (10H, m, aromatic), 7.70 (2H, d, J=15 Hz, vinylic) ppm. <sup>13</sup>C NMR (62.9MHz, CDCl<sub>3</sub>) δ 101.81, 124.09, 128.13, 128.94, 130.12, 135.00, 140.64, 183.33 ppm. EIMS m/z 278 (M<sup>+</sup>, 74.8%), 257 (18.9%), 229 (15.3%), 199 (24.3%), 171 (23.4%), 145 (38.7%), 131 (100%), 103 (93.9%), 77 (84.7%), 51 (37.8%).

1,7-bis(4-chloro phenyl)-1,6-heptadiene-3,5-dione 7b
Obtained as yellow crystalline solid. Yield (1.03 g, 60%), mp 161-162°C. IR ν<sub>max</sub>/cm<sup>-1</sup> 1640 (C=O), 1480 (C=C) <sup>1</sup>H NMR (90 MHz, CDCl<sub>3</sub>) δ 5.82 (1H, s, vinylic), 6.58 (2H, d, J=15 Hz, vinylic), 7.25-7.50 (8H, m, aromatic), 7.61 (2H, d, J=15 Hz, vinylic) ppm. EIMS m/z 345 (M<sup>+</sup>, 49.8%), 329
I, 7-bis(4-methoxy phenyl)-1,6-heptadiene-3,5-dione 7c
Obtained as yellow crystalline solid. Yield (1.06 g, 63%).
mp 170-171°C (lit mp 166-168°C). IR \( \nu_{\text{max/cm}^{-1}} \): 1620 (C=O), 1600 (C=C). \(^1\)H NMR (90 MHz, CDCl\(_3\)) \( \delta \): 3.82 (6H, s, OMe), 5.70 (1H, s, vinylic), 6.40 (2H, d, \( J=15 \) Hz, vinylic), 6.80 (4H, d, \( J=8 \) Hz, aromatic), 7.42 (4H, d, \( J=8 \) Hz, aromatic), 7.55 (2H, d, \( J=15 \) Hz, vinylic) ppm. EIMS m/z: 336 (M\(^+\), 18.5%), 318 (14.2%), 240 (13.1%), 161 (100%), 149 (57.1%), 135 (63.6%), 121 (69.7%)

I, 1-bis(methylthio)-5-(3-methoxyphenyl)-1,4-penta-
diene-3-one 26a
Obtained as yellow crystalline solid. Yield (0.78 g, 56%) mp 105-106°C. IR \( \nu_{\text{max/cm}^{-1}} \): 1620 (C=O), 1600 (C-H), 1480 (C=C). \(^1\)H NMR (90 MHz, CDCl\(_3\)) \( \delta \): 2.50 (6H, s, SMe), 3.80 (3H, s, OMe), 3.90 (3H, s, OMe), 6.20 (1H, s, vinylic), 6.75 (1H, d, \( J=15 \) Hz, vinylic), 6.84-7.30 (4H, m, aromatic), 7.55 (1H, d, \( J=15 \) Hz, vinylic) ppm.

I, 1-bis(methylthio)-5-(3,4-dimethoxyphenyl)-1,4-penta-
diene-3-one 26b
Obtained as yellow crystalline solid. Yield (0.84 g, 54%), mp 134-135°C. IR \( \nu_{\text{max/cm}^{-1}} \): 1640 (C=O), 1580 (C=C). \(^1\)H NMR (250 MHz, CDCl\(_3\)) \( \delta \): 2.52 (3H, s, SMe), 3.86 (3H, s, OMe), 3.90 (3H, s, OMe), 6.23 (1H, s, vinylic), 6.60 (1H, d, \( J=15 \) Hz, vinylic), 6.75 (1H, d, \( J=8 \) Hz, aromatic), 7.05-7.20 (2H, m, aromatic), 7.56 (1H, d, \( J=15 \) Hz, vinylic) ppm.
3.4.3 The reaction of 3-bis(methylthio)methylene pentane-2,4-dione with substituted benzaldehydes under acid catalyzed condition.

General Procedure.

To a cooled solution (0°C) of titanium tetrachloride (1.2 mL, 11 mmol), in dry dichloromethane (35 mL) diacetyl ketene dithioacetal (1.02 g, 5 mmol) and substituted benzaldehyde (10 mmol) dissolved in dichloromethane (10 mL) were added. After five minutes dry triethyl amine (1.5 mL, 11.5 mmol) dissolved in dichloromethane (5 mL) was added. The reaction mixture was stirred at 0°C for one hour. It was poured into ice water and brine. Extracted with ether. Organic phase was washed with water and brine. Dried over sodium sulphate. Filtered concentrated and chromatographed.

\[ 1,7\text{-bis(phenyl)}-4\text{-bis(methylthio)methylene-1,6-heptadiene-3,5-dione} \]

Obtained as orange yellow crystalline solid. Yield (0.51 g, 27%), mp 132-134°C. IR \( \nu_{\text{max}} \text{ cm}^{-1} \) 1620, 1580, 1460, 1160.

\(^1\text{H NMR} (200 \text{ MHz, CDCl}_3) \delta 2.45 (6\text{H, s, SMe}), 6.97 (2\text{H, d, } J=15 \text{ Hz, vinylic}), 7.26-7.41 (10\text{H, m, aromatic}), 7.65 (2\text{H, d, } J=15 \text{ Hz, vinylic}) \text{ ppm.} \)

\(^{13}\text{C NMR} (50.3 \text{ MHz, CDCl}_3) \delta 15.10, 17.29, 55.91, 55.97, 109.70, 111.07, 113.44, 122.69, 125.39, 128.26, 141.24, 149.16, 150.87 \text{ ppm.} \)

\[ 1,7\text{-bis(4-chlorophenyl)}-4\text{-bismethylthiocarboxyl)-1,6-heptadiene-3,5-dione} \text{ 28a} \]
Obtained as orange yellow crystalline solid. Yield (0.52 g, 25%), mp 173-174°C. IR $\nu_{\text{max}}$ cm$^{-1}$ 1620, 1480, 1420, 1080. $^1$H NMR (200 MHz, CDCl$_3$) $\delta$ 2.6 (3H, s, SMe), 6.9 (2H, d, $J$=15 Hz, vinylic), 7.2-7.5 (8H, m, aromatic), 7.7 (2H, d, $J$=15 Hz, vinylic) ppm. $^{13}$C NMR (50.3 MHz, CDCl$_3$) $\delta$ 13.73, 117.45, 121.24, 129.24, 129.70, 133.25, 136.59, 141.76, 180.00, 182.13, 183.92 ppm. EIMS m/z 418 (M$^+$, 16.1%) 371 (71.1%), 165 (100%), 137 (69.8%), 102 (72.5%).

1,7-bis(4-methoxyphenyl)-4-(methylthiocarboxy)-1,6-heptadiene-3,5-dione 28b

Obtained as orange yellow crystalline solid. Yield (0.50 g, 24%), mp 147-149°C. IR $\nu_{\text{max}}$ cm$^{-1}$ 1590, 1500, 1250, 1160, 1020. $^1$H NMR (300 MHz, CDCl$_3$) $\delta$ 2.5 (3H, s, SMe), 3.83 (6H, s, OMe), 6.5 (2H, d, $J$=15 Hz, vinylic), 7.25-7.65 (8H, m, aromatic), 7.7 (2H, d, $J$=15 Hz, vinylic) ppm.

### 3.4.4 Preparation of 3-(1,3-dithiolan-2-ylidene-2,4-pentanedione). (5)

To a suspension of KOH (5.6 g, 0.1 mol) in acetonitrile (30 mL) a mixture of acetyl acetone (10 mL, 0.1 mol) and carbon disulfide (6.5 mL, 0.1 mol) was added and stirred at room temperature for two hours. A solution of 1,2-dibromoethane (8.5 mL, 0.1 mol) in acetonitrile (10 mL) was added to this and the reaction mixture was stirred for another 24 hours. It was then diluted with benzene and washed with water and evaporated in vacum. The crude solid obtained was recrystallized from dichloromethane. mp 137-138°C (lit mp 136-137°C).
3.4.5 The reaction of 3-(1,3-dithiolan-2-ylidene)-2,4-pentanedione with aromatic aldehydes.

General procedure

To catalytic amount of sodium metal dissolved in ethanol (20 mL) cyclic diacetyl ketene dithioacetal (1.01 g, 5 mmol) was added followed by aldehyde (10 mmol). The reaction mixture was stirred at 0-5°C for four hours. The solid product obtained was filtered, washed with ethanol and recrystallized from a mixture of hexane and ethyl acetate.

\[
\text{1,7-bis(phenyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione. 29a}
\]

Obtained as yellow crystalline solid. Yield (0.98 g, 60%), mp 156-158°C. IR \(\nu_{\text{max}}/\text{cm}^{-1}\) 1620, 1580, 1380, 1330. \(^1\)H NMR (250 MHz, CDCl\(_3\)) \(\delta\) 3.4 (4H, s, SCH\(_2\)), 6.9, (2H, d, \(J=15\) Hz, vinylic), 7.3-7.5 (10H, m, aromatic), 7.7 (2H, d, \(J=15\) Hz, vinylic) ppm. \(^13\)C NMR (62.9 MHz, CDCl\(_3\)) \(\delta\) 37.3, 125.92, 127.89, 128.41, 128.93, 130.51, 134.75, 143.77, 187.80 ppm EIMS m/z 378 (M\(^+\), 33.9%), 287 (13.5%), 144 (15.1%), 131 (58.2%), 103 (100%), 91 (38%), 77, (43%).

\[
\text{1,7-bis(4-methoxyphenyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 29d}
\]

Obtained as yellow crystalline solid. Yield (1.4 g, 64%), mp 109-110°C. IR \(\nu_{\text{max}}/\text{cm}^{-1}\) 1620, 1580, 1380, 1330. \(^1\)H NMR (90 MHz, CDCl\(_3\)) \(\delta\) 3.4 (4H, s, SCH\(_2\)), 3.7 (6H, s, OMe), 6.9-7.7. (12H, m, aromatic & vinylic) ppm. EIMS m/z 438 (M\(^+\), 11.8%), 277 (16.4%), 161 (100%), 145 (28.6%), 133 (39.1%), 121 (54.3%), 77 (15.2%).

\[
\text{1,7-bis(3,4-dimethoxyphenyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 29e}
\]
Obtained as yellow crystalline solid. Yield (1.52 g, 61%). mp 128-129°C. IR v<sub>max</sub>/cm<sup>-1</sup> 1620, 1580, 1500, 1400. <sup>1</sup>H NMR (90 MHz, CDCl<sub>3</sub>) δ 3.3 (4H, s, SCH₂), 3.7 (6H, s, OMe), 3.9 (6H, s, OMe), 6.7-7.2 (8H, m, aromatic & vinylic), 7.7 (2H, d, J=15 Hz vinylic) ppm. EIMS m/z 498 (M<sup>+</sup>, 9.7%), 202 (22.1%), 174 (55.1%), 151 (37.1%), 145 (100%), 91 (14.8%).

1,7-bis(4-chlorophenyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 29b

Obtained as yellow crystalline solid. Yield (1.5 g, 67.5%). mp 164-165°C. IR v<sub>max</sub>/cm<sup>-1</sup> 1620, 1580, 1560. <sup>1</sup>H NMR (90 MHz, CDCl<sub>3</sub>) δ 3.4 (4H, s, SCH₂), 6.9 (2H, d, J=15 Hz, vinylic), 7.2-7.5 (8H, m, aromatic) 7.6 (2H, d, J=15 Hz, vinylic) ppm. <sup>13</sup>C NMR (22.5 MHz, CDCl<sub>3</sub>) δ 837, 126, 129, 133, 136, 142, 188 ppm. EIMS m/z 446 (M<sup>+</sup> 32.4%), 323 (20.4%), 282 (13.3%), 178 (28.3%), 165 (50.0%), 145 (64.9%), 131 (70.7%), 125 (64.9%), 103 (100%), 77 (49.3%).

1,7-bis(3-methoxyphenyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 29c

Obtained as yellow crystalline solid. Yield (1.37 g, 63%). mp 104-105°C. IR v<sub>max</sub>/cm<sup>-1</sup> 1620, 1580, 1480, 1380. <sup>1</sup>H NMR (90 MHz, CDCl<sub>3</sub>) δ 3.4 (4H, s, SCH₂), 3.7 (6H, s, OMe), 6.9-7.3 (10H, m, aromatic & vinylic), 7.7 (2H, d, J=15 Hz, vinylic) ppm. EIMS m/z 438 (M<sup>+</sup>, 11.8%), 278 (6.0%), 175 (3.3%), 145 (28.6%), 131 (100%), 103 (9.4%), 77 (15.2%).

1,7-bis(furyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 31a

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Prepared by BeeHive Digital Concepts Cochin for Mahatma Gandhi University Kottayam
Obtained as yellow crystalline solid. Yield (1.15 g, 64%) mp 127-128°C. IR $\nu_{\text{IR}}$ cm$^{-1}$ 1620, 1580, 1540, 1420. $^1$H NMR (90 MHz, CDCl$_3$) $\delta$ 3.3 (4H, s, SCH$_2$), 6.4-7.7 (10H, m, aromatic & vinylic) ppm. EIMS m/z 358 (M$^+$, 100%), 290 (17.6%), 147 (18.6%), 175 (53%), 121 (70.5%), 103 (62.6%), 77 (68.2%).

1,7-bis(thienyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 31b

Obtained as yellow crystalline solid. Yield (1.22 g, 61%), mp 135-136°C. IR $\nu_{\text{IR}}$ cm$^{-1}$ 1620, 1560, 1460, 1260. $^1$H NMR (90 MHz, CDCl$_3$) $\delta$ 3.3 (4H, s, SCH$_2$), 6.7-7.9 (10H, m, aromatic & vinylic) ppm. EIMS m/z 390 (M$^+$, 8.1%), 306 (8.5%), 253 (29.3%), 137 (61.5%), 111 (100%), 109 (36.3%).

3.4.6 Preparation of 2-(1,3-dithiolan-2-ylidene)-1-phenyl-1,3-butanedione (32)

To a suspension of potassium carbonate (14 g, 0.1 mol) in acetonitrile (30 mL) a mixture of benzoyl acetone (16.2 g, 0.1 mol) and carbon disulfide (6.5 mL, 0.1 mol) was added and stirred at room temperature. After two hours 1,2-dibromo ethane (8.5mL, 0.1 mol) was added and stirred at room temperature for another 24 hours. The reaction mixture was diluted with benzene washed with water and evaporated in vaccum. The crude solid obtained was recrystallized from a mixture (1:1) of petroleum ether and benzene. mp 49-50°C (lit mp 50°C)\textsuperscript{26-28}
3.4.7 Reaction of 2-(1,3-dithiolan-2-ylidene)-1-phenyl-1,3-butanedione with aromatic aldehydes

General procedure

To a catalytic amount of sodium dissolved in ethanol (20 mL) the cyclic ketene dithioacetal (1.32 g, 5 mmol) was added followed by aldehyde (5 mmol). The reaction mixture was stirred at 0-5°C for four hours. The yellow solid obtained was filtered and recrystallized from a mixture of hexane and ethyl acetate.

1,5-bis(phenyl)-2-(1,3-dithiolan-2-ylidene)-4-pentene-1,3-dione 33a

Obtained as yellow crystalline solid. Yield (0.92 g, 52%), mp 176-177°C. IR ν㎝⁻¹ 1610, 1580, 1420, 1200. ¹H NMR (90 MHz, CDCl₃) δ 3.35 (4H, s, SCH₂), 6.4 (1H, d, J=15 Hz vinylic), 7.15-7.9 (11H, m, aromatic & vinylic) ppm. EIMS m/z 352 (M⁺, 17.5%), 264 (29.1%), 236 (46.1%), 105 (45%), 77 (100%).

1-(phenyl)-5-(4-methoxy phenyl)-2-(1,3-dithiolan-2-ylidene)-4-pentene-1,3-dione 33b

Obtained as yellow crystalline solid. Yield (1.03 g, 54%), mp 163-164°C. IR ν㎝⁻¹ 1640, 1580, 1500, 1460, 1160. ¹H NMR (90 MHz, CDCl₃) δ 3.4 (4H, s, SCH₂), 3.8 (3H, s, OMe), 6.3-7.8 (11H, m, aromatic & vinylic) ppm. EIMS m/z 382 (M⁺, 21.7%), 264 (37.1%), 236 (46.6%), 105 (100%), 77 (70.1%).
3.4.8 Reaction of 1,7-bis(phenyl)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione with sulfoxonium methylide

The condensation product (1.76 g, 5 mmol) was dissolved in dichloromethane (20 mL). 50% NaOH solution (20 mL) was added followed by the phase transfer catalyst (3.6 g, 10 mmol). The reaction mixture was stirred at room temperature for twenty minutes. Then sulfoxonium salt (4.4 g, 20 mmol) was then added and the reaction mixture was again stirred at room temperature overnight. It was then washed with water and extracted with dichloromethane. The dichloromethane was then removed and ethylacetate added. The precipitated PTC was filtered off and the filtrate was evaporated to give a viscous residue which was subjected to column chromatography.

1,3-bis(Cyclopropyl-2-phenyl)-1,3-propanone

Obtained as yellow solid. Yield (0.83 g, 41%), mp 155-157°C. IR \nu_{max}/cm\(^{-1}\) 1600, 1410, 1220, 900. \(^1\)H NMR (200 MHz, CDCl\(_3\)) \delta 3.3 (4H, s, SCH\(_2\)), 6.7-7.25 (10H, m, aromatic), 1.15 (2H, m, CH\(_2\)), 1.45 (2H, m, CH\(_3\)), 1.85 (1H, m, CH\(_2\)), 2.48 (1H, m, CH), 2.6 (1H, m, CH), 2.8 (1H, m, CH) ppm. \(^13\)C NMR (50.3 MHz, CDCl\(_3\)) \delta 20.39 (CH\(_2\)), 20.90 (CH\(_2\)), 30.46 (CH), 30.91 (CH), 33.31 (CH), 35.17 (CH), 36.99 (SCH\(_2\)), 37.14 (SCH\(_2\)), 126.0, 128.4, 140.0, 195.57 (C=O), 196.10 (C=O) ppm. EIMS m/z 406 (M\(^+\), 13.8%), 302 (100%), 245 (20.1%), 184(16.8%), 145 (31.5%), 115 (47%), 91 (42.3%).

3.4.9 Preparation of 1,7-bis-(N,N-dimethylamino)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione

A mixture of cyclic ketene dithioacetal (606 mg, 3 mmol) and DMF acetal (0.75 mL, 3.2 mmol) was heated (100°C) under nitrogen atmosphere for 5h. The reaction mixture was cooled and the red solid seperated was filtered and washed with ether.
1,7-bis(N,N-dimethylamino)-4-(1,3-dithiolan-2-ylidene)-1,6-heptadiene-3,5-dione 36

Obtained as red solid. Yield (855 mg, 92%), mp 105-107°C. IR \( \nu_{\text{max}} / \text{cm}^{-1} \) 1620, 1570, 1480, 1340, 1270, 1220 \( ^1H \) NMR (90 MHz, CDCl\(_3\)) \( \delta \) 2.2 (12H, s, NCH\(_3\)), 3.2 (4H, s, SCH\(_2\)), 5.2 (2H, d, \( J=12 \) Hz, vinylic), 7.6 (2H, d, \( J=12 \) Hz, vinylic) ppm.

3.4.10 Cycloaddition reactions of bis(cinnamoyl) ketene dithioacetal 29a

The bis(cinnamoyl) ketene dithioacetal 29a (378 mg, 1 mmol) was dissolved in toluene (30 mL). Lawesson's reagent (600 mg, 1.5 mmol) was added to it and refluxed at 120°C for one hour. Maleic anhydride (400 mg, 4 mmol) was added and the reaction mixture was again refluxed for another seven hours. Toluene was distilled off from the reaction mixture and the residue subjected to column chromatography using hexane:ethylacetate (90:10) as the eluent.

Obtained as yellow crystalline solid. Yield (58%), mp 188-190°C. IR \( \nu_{\text{max}} / \text{cm}^{-1} \) 3450, 1660, 1530, 1260, 1140, 760, 700. \( ^1H \) NMR (300 MHz, CDCl\(_3\)) \( \delta \) 7.25-7.4 (m), 2.45-2.85 (m), 3.15-3.37 (m), 3.41-3.64 (m), 3.78-3.96 (m), 4.29-4.37 (m), 4.61-4.69 (m) ppm. \( ^{13}C \) NMR \( \delta \) 40.45, 41.08, 41.47, 42.30, 44.06, 44.39, 46.00, 46.69, 47.37, 71.51, 71.12, 127.27, 127.36, 127.84, 128.35, 128.50, 128.79, 128.94, 137.00, 137.63, 138.34, 156.69, 159.97, 189.45, 190.43 ppm. FABMS 429 (100%), 363 (79.2%), 336 (44.8%), 307 (27.1%), 265 (25%), 231 (14.6%), 203 (16.7%), 171 (22.9%),
3.5 References