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Supporting Information

Synthesis of hexahydroquinoline (HHQ) derivatives using $ZrOCl_2.8H_2O$ as a potential green catalyst and optimization of reaction condition using design of experiment (DOE)

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Design of Experiment

Experimental design technique was used to investigate the effect of temperature and amount of $ZrOCl_2.8H_2O$ as the catalyst on the yield of the reaction.

Central composite design (CCD) is used as a response surface methodology. This experimental plan is very efficient in fitting second-order models, is nearly rotatable, and have a potentially practical advantage of experimenting with three equally spaced levels over the experimental region.

The plan of central composite design for 2 factors is shown in the Fig. 1.

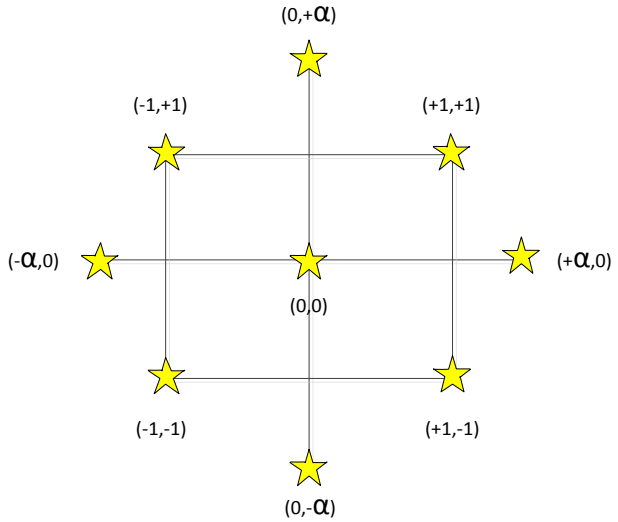

Fig. 1 The plan of central composite design for 2 factors

- Four corners of the square represent the factorial (+/-1) design points
- Four star points represent the axial (+/-α) design points
- Replicated center point (0,0)

In the CCD the alpha was set as 1. The design space, coded, and actual values are shown in Table 1.

Table 1 Levels of the experimental variables and the corresponding response values of the Central Composite Design.

temperature	catalyst	temperature	catalyst	Yield
X_1	X_2	X_1	X	response
75.00	0.10	0	0	92
100.00	0.10	1	0	85
50.00	0.05	-1	-1	67
75.00	0.10	0	0	91
75.00	0.05	0	-1	88
50.00	0.15	-1	1	73
50.00	0.10	-1	0	67
100.00	0.15	1	1	93
100.00	0.05	1	-1	73
75.00	0.10	0	0	93
75.00	0.15	0	1	95

We can use the Taylor expansion and relate the response to the variables such as

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \mathrm{L} + \beta_k x_k + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \mathrm{L} + \beta_{k\text{-}1,k} x_{k\text{-}1} x_k + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \mathrm{L} + \beta_{kk} x_k^2 + \varepsilon \quad (1)$$

Thus we have some experimental data (X and Y) and we want to obtain the coefficient of equation (1). If we define the error between experimental and predicted value as equation (2), this error must be minimized.

$$error = \sum_{i=1}^{n} \left(Y_{\mathrm{exp}erimental} - Y_{prediction} \right)^2 \quad (2)$$

Minimizing error with respect to the β's involves differentiating error with respect to β_1, β_2, …, β_n and equating the n partial derivatives to zero. This yields n equations that relate the n unknown values of the estimated coefficients β_1, β_2, …, β_n. also we can use matrix form to obtain β_1, β_2, …, β_n as bellow:

$\beta=(X^TX)^{-1}(X^TY)$

In equation (1) β_1, β_2, …, β_n are unknown and the x1, x2, and Y are known. If we calculate the beta coefficients, we have:

$$X = \begin{bmatrix} & x_1 & x_2 & x_1 \times x_2 & x_1^2 & x_2^2 \\ 1 & 75 & 0.10 & 7.50 & 5625 & 0.0100 \\ 1 & 100 & 0.10 & 10.0 & 10000 & 0.0100 \\ 1 & 50 & 0.05 & 2.50 & 2500 & 0.0025 \\ 1 & 75 & 0.10 & 7.50 & 5625 & 0.0100 \\ 1 & 75 & 0.05 & 3.75 & 5625 & 0.0025 \\ 1 & 50 & 0.15 & 7.50 & 2500 & 0.0225 \\ 1 & 50 & 0.10 & 5.00 & 2500 & 0.0100 \\ 1 & 100 & 0.15 & 15.00 & 10000 & 0.0225 \\ 1 & 100 & 0.05 & 5.00 & 10000 & 0.0025 \\ 1 & 75 & 0.10 & 7.50 & 5625 & 0.0100 \\ 1 & 75 & 0.15 & 11.25 & 5625 & 0.0225 \end{bmatrix}$$

The matrix of experimental reaction time:

$$Y = yield = \begin{bmatrix} 92 \\ 85 \\ 67 \\ 91 \\ 88 \\ 73 \\ 67 \\ 93 \\ 73 \\ 93 \\ 95 \end{bmatrix}$$

After computing the matrix, β is obtained as follows:

$$\beta = (X^T X)^{-1}(X^T Y) = \begin{bmatrix} -59.368 \\ 3.727 \\ -102.105 \\ 2.800 \\ -0.023 \\ 10.526 \end{bmatrix}$$

$$Y(Yield) = -59.37 + 3.73X_1 - 102.10X_2 + 2.8X_1X_2 - 0.025X_1^2 + 10.53X_2^2 \quad (3)$$

After optimization of yield with the lower ([50 0.05]) and upper bound ([100 0.15]) of the reaction condition, the optimum condition obtained as bellow:

X^*=[83.75 0.15]

Proposed mechanism

The proposed mechanism is shown in the Fig. 2.

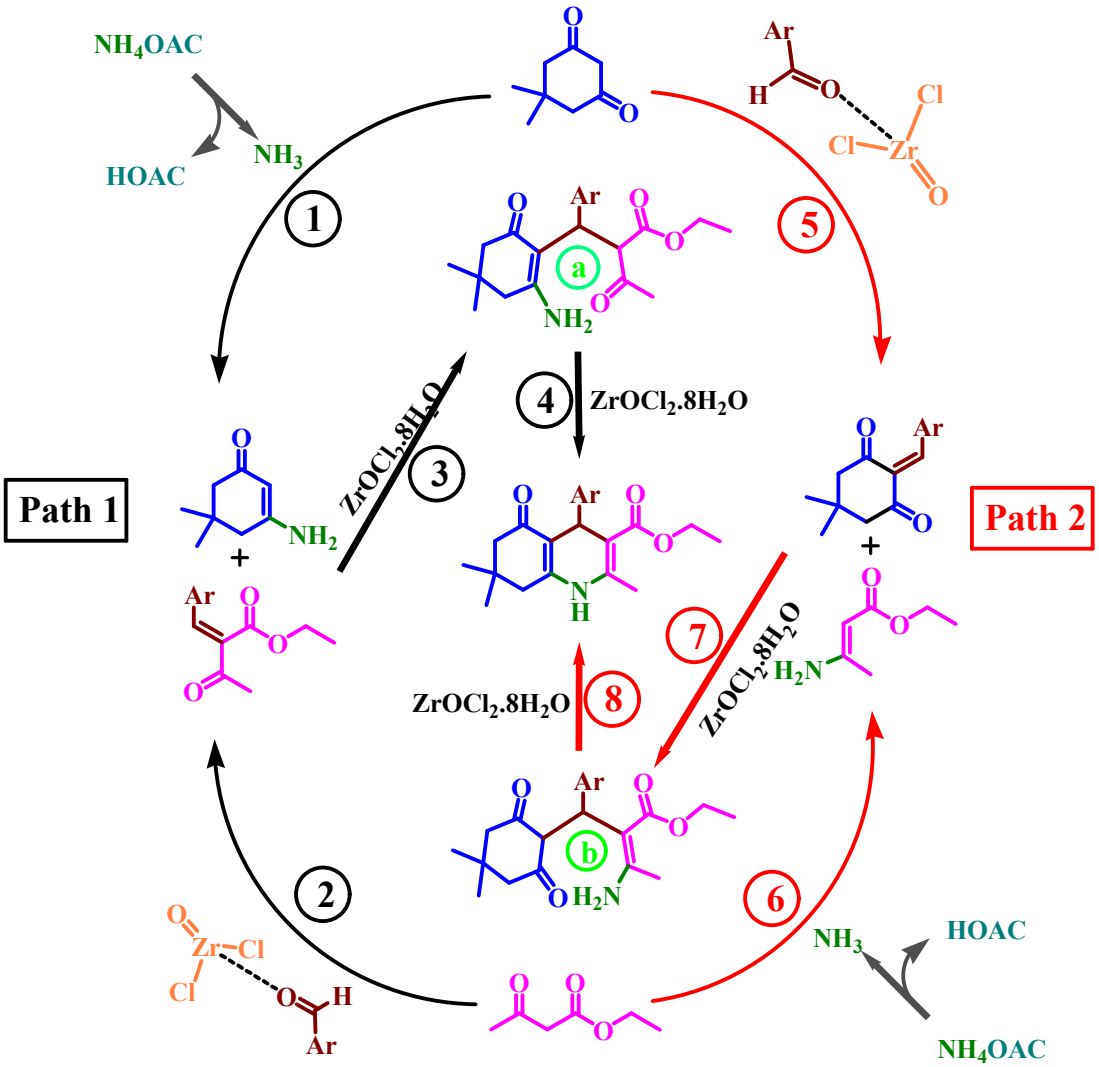

Fig. 2 The possible mechanism for the synthesis of hexahydroquinolines derivatives catalyzed by $ZrOCl_2$

To investigate the possible mechanism and the proper role of $ZrOCl_2$ Infrared (IR) technique was used.

- In order to find the possible interaction of $ZrOCl_2$ with the reactants, three separate reactions carried out by $ZrOCl_2$ and benzaldehyde, dimedone, and ethyl acetoacetate, respectively. Based on the shift of the carbonyl group in the benzaldehyde from 1686.43 cm^{-1} to 1703.67 cm^{-1} in IR spectra, it was shown that the $ZrOCl_2$ linkages only with benzaldehyde (Fig. 3):

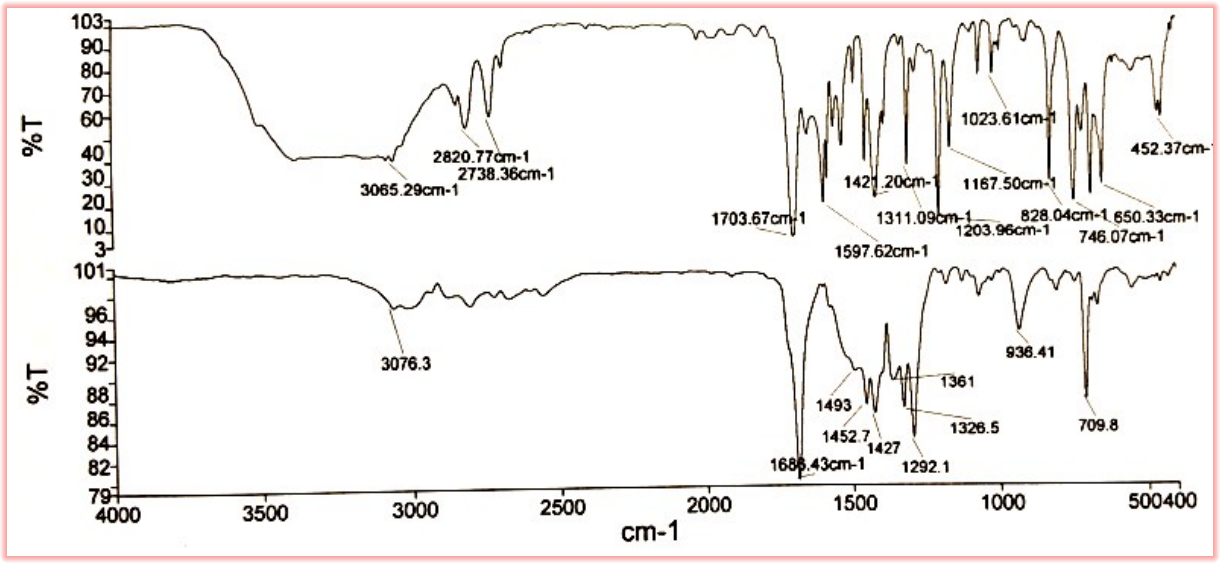

Fig. 3 IR spectra of benzaldehyde (upper) and benzaldehyde+ $ZrOCl_2$ mixture (lower)

- A reaction was carried out between ammonium acetate and dimedone to clear out the interaction between them. Appearing the α, β-unsaturated ketones frequency at 1660.3 cm^{-1} in the mixture of the reaction shows that ammonium acetate reacts with the dimedone (Fig. 4).

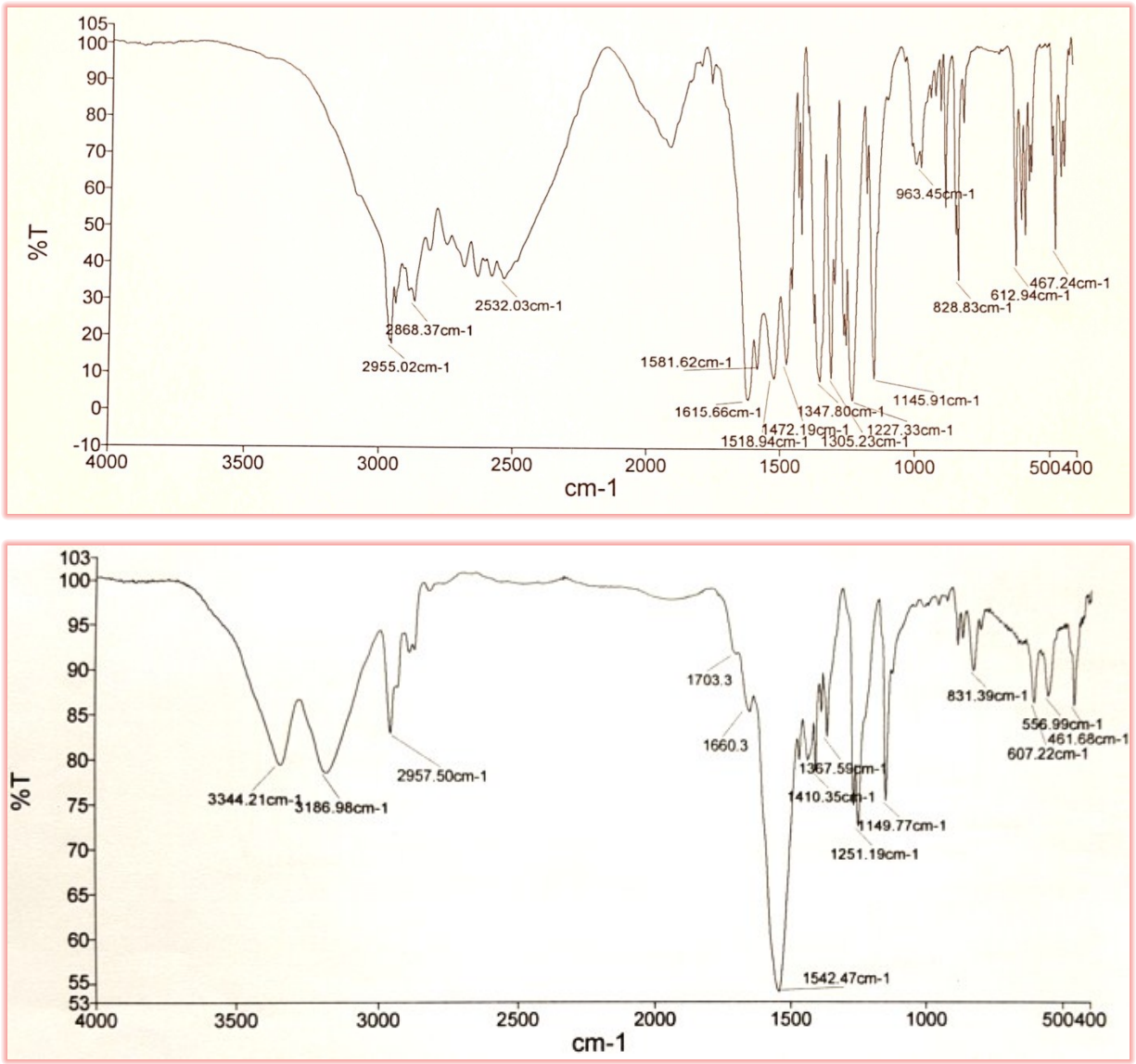

Fig. 4 IR spectra of dimedone (upper) and dimedone+ ammonium acetate mixture (lower)

- A reaction was carried out between ammonium acetate and ethyl acetoacetate to clear out the interaction between them. IR spectrum of the reaction mixture shows that two sharp peak of ethyl acetoacetate's carbonyl groups converts to one carbonyl group. It is a clue that ammonium acetate reacts with the ethyl acetoacetate (Fig. 5).

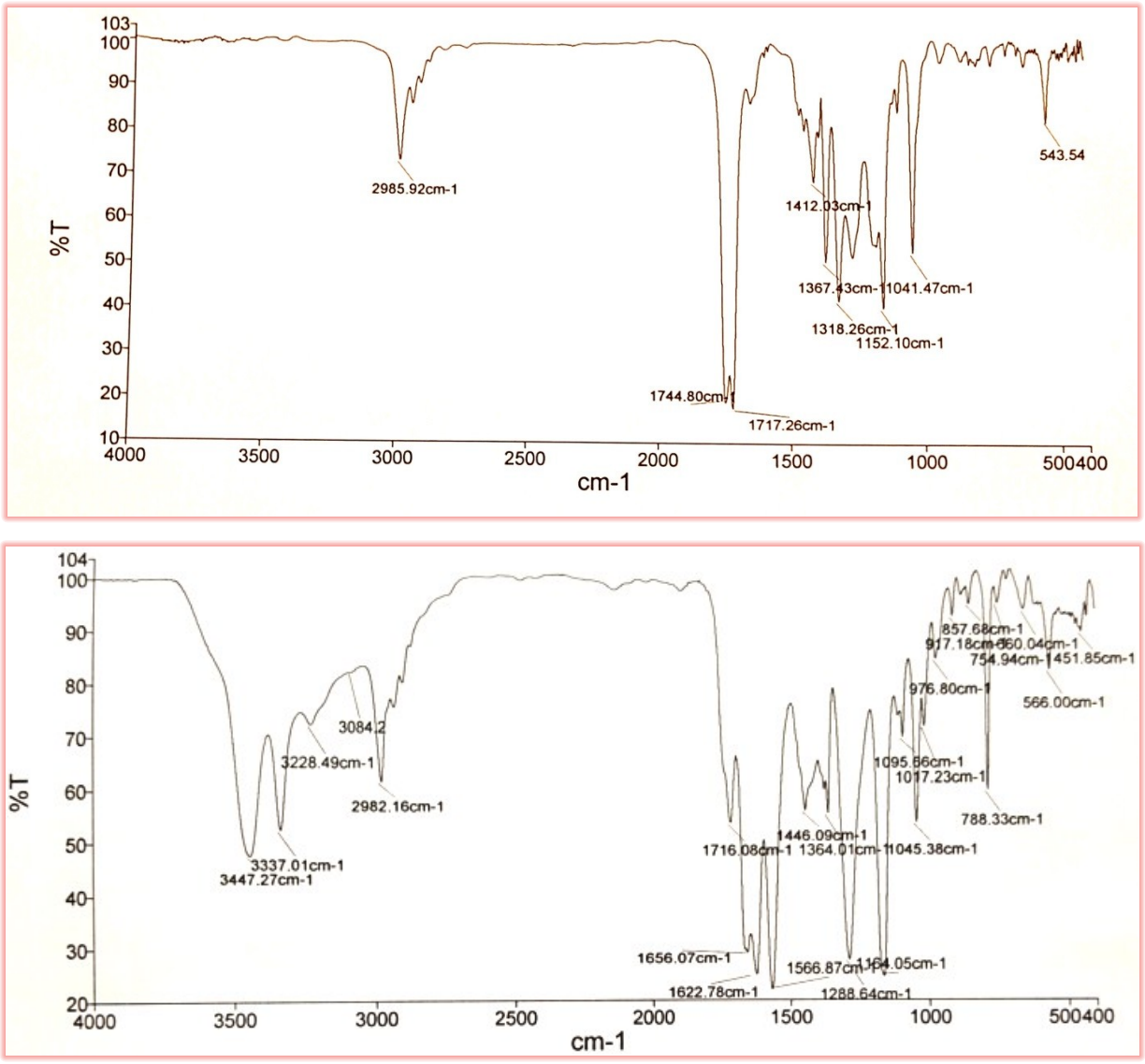

Fig. 5 IR spectra of ethyl acetoacetate (upper) and ethyl acetoacetate+ ammonium acetate mixture (lower)

- Another reaction was performed between reactants (ammonium acetate+ethyl acetoacetate+dimedone+benzaldehyde), so that the reaction stopped at 20 seconds to identify intermediates. Two intermediate were identified and separated using plate. IR spectra of the first intermediate are given in the Fig. 6:

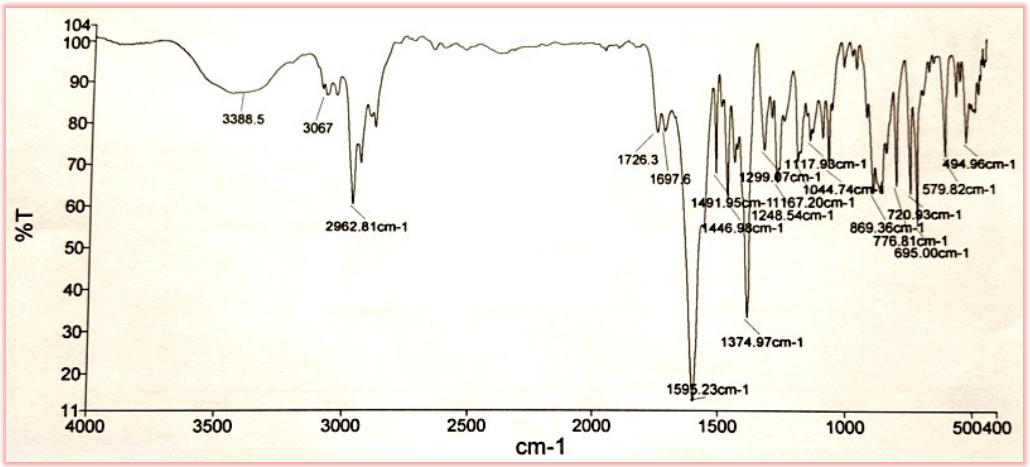

Fig. 6 IR spectrum of separated intermediate

As it shown in the Fig. 6, this IR spectrum has the flowing specific functional groups:

1. 1726.3 cm^{-1} is related to α, β-unsaturated esters.
2. 1697.6 cm^{-1} is related to general carbonyl group.
3. 2962.81 cm^{-1} is related to the C-H stretch of aromatic.
4. 3388.5 cm^{-1} and 1595.23 cm^{-1} is related to N-H stretch and N-H bend, respectively of 1° amine

These peaks most probably can be related to the intermediate which has been determined by b in the Fig. 7.

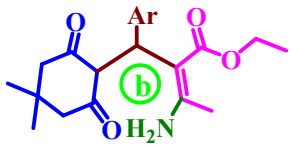

Fig. 7 Intermediate which generated by path 2 in Fig. 2.

The IR spectrum of the second intermediate is given in the Fig. 8 with the following functional groups.

5. 1. 1668.9 cm^{-1} is related to α, β-unsaturated ketone.
6. 1697.6 cm^{-1} is related to general carbonyl group.
7. 1729.2 cm^{-1} is related to α, β-unsaturated esters.
8. 2962.71 cm^{-1} is related to the C-H stretch of aromatic.
9. 3331.1 cm^{-1} and 1595.02 cm^{-1} is related to N-H stretch and N-H bend, respectively of 1° amine

10. These peaks most probably can be related to the intermediate which has been determined by a in the Fig. 9.

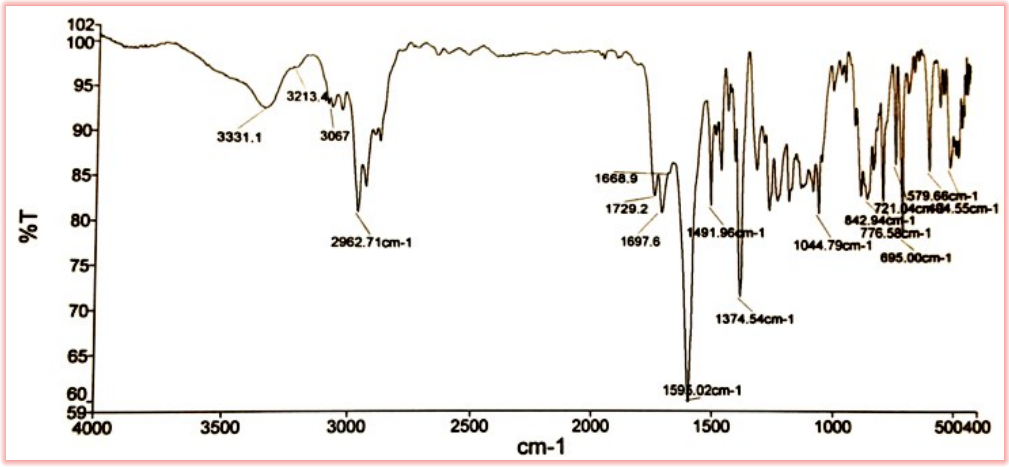

Fig. 8 IR spectrum of separated intermediate

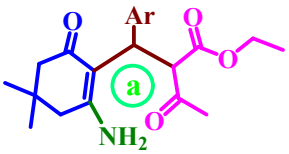

Fig. 9 Intermediate which generated by path 1 in Fig. 2.

Material data

Ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxo-4-phenylquinoline-3-carboxylate (1). White solid; melting point: 219-222°C; IR (KBr): 3290, 3081, 2962, 1699, 1644, 1611, 1484, 1381, 1212 cm^{-1}.

Ethyl 4-(2-chlorophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate (11).

White solid; melting point: 205-207°C; IR (KBr): 3292, 3071, 2959, 1698, 1639, 1608, 1483, 1378,1278, 1212; ^{1}HNMR (500 MHz, DMSO-d_6): δ (ppm) 0.83 (s,3H),1.00 (s,3H), 1.07 (t, J=5.0 Hz, 3H), 2.02 (d, 2H), 2.23 (s, 3H), 2.50 (s,2H), 3.93 (q, J=5.0 Hz, 2H), 5.17 (s,1H), 7.07 (t, J=10.0 Hz, 1H), 7.17 (t, J=5.0 Hz, 1H), 7.21 (d, J=10.0 Hz, 1H), 7.27 (d, J=5.0 Hz, 1H), 9.11 (s,1H); ^{13}CNMR (125 MHz, DMSO-d_6): δ (ppm) 14.93, 18.94, 19.02, 27.19, 29.97, 32.80,

35.77, 51.08, 59.83, 104.15, 110.42, 127.48, 128.12, 129.85, 132.36, 132.77, 145.88, 150.56, 150.68, 167.68, 194.88.

Ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-4-(2-nitrophenyl)-5-oxoquinoline-3-carboxylate (2).

Yellow solid; melting point: 205-207°C; IR (KBr): 3294, 2966,1711, 1698, 1617, 1529, 1380, 1283 cm^{-1}; ^{1}HNMR (500 MHz, $CDCl_3$): δ (ppm) 0.91 (s, 3H), 1.06 (s, 3H), 1.13 (t, J=5.0 Hz, 3H), 2.15 (d, J=15.0 Hz, 2H), 2.29 (s, 2H), 2.34 (s, 3H), 4.00-4.14 (m, 2H), 5.92 (s,1H), 7.08 (s, 1H), 7.26 (t, J=5.0 Hz, 1H), 7.50 (t, J=5.0 Hz, 1H), 7.57 (d, J=5.0 Hz, 1H), 7.76 (d, J=5.0 Hz, 1H); ^{13}CNMR (125 MHz, $CDCl_3$): δ (ppm) 14.5, 19.44, 27.51, 29.54, 32.89, 32.96, 40.91, 51.16, 60.35, 105.33, 111.48, 124.28, 127.09, 131.60, 133.12, 142.43, 145.85, 148.72, 150.89, 167.82 .

Ethyl 4-(4-bromophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate (3).

White solid; melting point: 257-259°C; IR (KBr): 3278, 3076, 2959, 1703, 1648, 1604, 1489, 1380, 1280, 1214 cm^{-1}; ^{1}HNMR (500 MHz, DMSO-d_6): δ (ppm) 0.83 (s,3H), 1.00 (s, 3H), 1.11 (t, J=5.0 Hz, 3H), 2.06 (d, 2H), 2.28 (s, 3H), 2.50 (s,2H), 3.96 (q, J=5.0 Hz, 2H), 4.82 (s, 1H), 7.10 (d, J=5.0 Hz, 2H), 7.38 (d, J=5.0 Hz, 2H), 9.13 (s,1H); ^{13}CNMR (125 MHz, DMSO-d_6): δ (ppm) 14.96, 19.07, 19.14, 27.27, 29.93, 32.97, 36.57, 51.00, 60.01, 103.96, 103.99, 110.43, 110.46, 119.59, 130.63,131.46, 146.27, 147.84,150.61, 167.54, 195.26.

Ethyl 4-(4-(dimethylamino) phenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate (4).

Cream solid; melting point: 233-235°C; IR (KBr): 3280, 3078, 2956, 2801, 1702, 1684, 16.06, 1517, 1489, 1379, 1222 cm^{-1}; ^{1}HNMR (500 MHz, $CDCl_3$): δ (ppm) 0.99 (s,3H), 1.09 (s,3H), 1.27 (t, J=10.0 Hz, 3H), 2.19 (d, 2H), 2.25 (d, 2H), 2.38 (s,3H), 2.89 (s, 6H), 4.10 (q, J=10.0 Hz, 2H), 5.02 (s,1H), 6.43 (s,1H), 6.62 (d, J=10.0 Hz, 2H), 7.19 (d, J=10.0 Hz, 2H); ^{13}CNMR (125 MHz, $CDCl_3$): δ (ppm) 14.77, 19.56, 27.61, 30.01, 32.98, 35.85, 40.88, 41.10, 51.32, 60.10, 106.68, 112.21, 112.66, 129.03, 136.49, 144.10, 149.34, 150.19, 168.30.

Ethyl 4-(2-fluorophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate (5).

White solid; melting point: 231-234°C; IR (KBr): 3291, 3079, 2962, 1700, 1645, 1610, 1485, 1381, 1310, 1279, 1211 cm^{-1}; ^{1}HNMR (500 MHz, DMSO-d_6): δ (ppm) 0.83 (s, 3H), 1.00 (s, 3H), 1.08 (t, J=5.0 Hz, 3H), 1.92 (d, 1H), 2.15 (d,1H), 2.24 (s,3H), 2.50 (s,2H), 3.92 (q, J=10.0 Hz, 2H), 5.04 (s, 1H), 6.95 (t, J=10.0 Hz, 1H), 7.01 (t, J=5.0 Hz, 1H), 7.10 (q, J=10.0 Hz, 1H), 7.19

(t, J=5.0 Hz, 1H), 9.10 (s, 1H); ^{13}CNMR (125 MHz, DMSO-d_6): δ (ppm) 14.73, 19.03, 27.06, 29.97, 31.88, 32.89, 51.00, 59.85, 103.62, 109.88, 115.55, 115.73, 124.54, 128.41, 131.66, 135.38, 146.13, 150.75, 159.14, 161.11, 167.58, 194.94.

Ethyl 4-(2,4-dichlorophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate (6).

White solid; melting point: 244-245°C; IR (KBr): 3282,3075, 2930, 1706, 1610, 1493, 1380, 1213 cm^{-1}; 1H NMR (400 MHz, DMSOd6): δ (ppm) 0.83 (s, 3H), δ 0.92 (s, 3H), 1.07 (t, J =7.08 Hz, 3H), 1.91 (d, J =16.04 Hz, 1H), 2.14 (d, J =16.08 Hz, 1H), 2.22 (s, 3H), 2.49-2.50 (Distorted AB system, 2H), 3.95-3.91 (m, 2H), 5.14 (s, 1H), 7.31 (s, 2H), 7.34 (s, 1H), 9.12 (s, 1H); 13C NMR (100 MHz, DMSO-d6): δ (ppm) 14.07, 18.19, 26.37, 29.01, 31.94, 34.73, 50.14, 58.99, 102.69, 109.18, 126.83, 128.16, 130.70, 132.75, 132.82,144.19, 145.44, 149.85, 196.30.

Ethyl 4-(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate (7).

White solid; melting point: 243-245°C; IR (KBr): 3275, 3077, 2959, 1706, 1648, 1605, 1489, 1381, 1280, 1214 cm^{-1}; ^{1}H NMR (400 MHZ, DMSO-d_6): δ (ppm) 0.82 (s, 3H), 0.99 (s, 3H), 1.11 (t, J = 7.08 Hz, 3H), 1.97 (d, J =16.08, 3H), 2.16 (d, J =16.12 Hz,1H), 2.43-2.50 (Distorted AB system, 2H), 3.96 (d, J =7.08 Hz, 2H), 4.83 (s, 1H), 7.15 (d, J=8.48, 2H), 7.24 (d, J =8.44, 2H), 9.01 (s, 1H).

Ethyl 1,4,5,6,7,8-hexahydro-4-(3-hydroxyphenyl)-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate (8).

White solid; melting point: 228-230°C; IR (KBr): 3408, 3289, 1675, 1606, 1485, 1220 cm^{-1}; 1H NMR (400 MHz, DMSO-d6): δ (ppm) 0.86 (s, 3H), 1.00 (s.3H). 1.13 (t, J =7.04 Hz, 3H), 2.00 (s, 1H), 2.15 (d, J =16.08 Hz, 1H), 2.26 (s, 3H), 2.38-2.50 (Distorted AB system, 2H), 3.97 (q, J =7.08 Hz, 2H), 4.78 (s, 1H), 6.46-6.43 (m, 1 H), 6.57 (d, J =7.24 Hz, 2H), 6.93 (t, J =7.96 Hz,1H), 9.01 (s,1H), 9.06 (s, 1H) ; 13C NMR (100 MHz, DMSO-d6): δ (ppm) 14.8, 18.9, 27.4, 29.8, 32.8, 36.4, 40.4, 51.2, 59.7, 104.6, 110.8, 113.4, 115.4, 119.0, 129.3, 145.4, 150.2, 157.7, 167.8, 195.0.

Ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxo-4-p-tolylquinoline-3-carboxylate (9).

White solid; melting point: 264-265°C; IR (KBr): 3275, 3077, 2958, 1702, 1647, 1606, 1493, 1380, 1281; ^{1}HNMR (500 MHz, $CDCl_3$): δ (ppm) 0.98 (s,3H), 1.10 (s, 1H), 1.25 (t, J=5.0 Hz, 3H), 2.23 (d, J=5.0 Hz, 2H),2.28 (s, 2H), 2.37 (s,3H), 4.105 (q, J=5.0 Hz, 2H), 5.05 (s,1H), 6.49 (s,1H), 7.03 (d, J=10.0 Hz, 2H), 7.22 (d, J=10.0 Hz, 2H); ^{13}CNMR (125 MHz, $CDCl_3$): δ (ppm)

14.67, 19.75, 21.48, 27.63, 29.87, 33.12, 36.54, 41.40, 51.22, 60.21, 106.59, 112.56, 128.29, 129.03, 135.80, 143.87, 144.65, 148.91, 167.97 .

Ethyl 1,4,5,6,7,8-hexahydro-4-(3-methoxyphenyl)-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate (10).

White solid; melting point: 204-206°C; IR (KBr): 3285, 3079, 2967, 1689, 1642, 1610, 1488, 1381, 1282; ^{1}HNMR (500 MHz, $CDCl_3$): δ (ppm) 0.98 (s,3H), 1.09 (s, 3H), 1.25 (t, J=10.0 Hz, 3H), 2.24 (d, 2H), 2.31 (s,2H), 2.37 (s, 3H), 3.78 (s, 3H), 4.11 (q, J=10.0 Hz, 2H), 5.08 (s, 1H), 6.49 (s,1H), 6.68 (d, J=5.0 Hz, 1H), 6.90 (t, J=1.5 Hz, 1H), 6.94 (d, J=10.0 Hz, 1H), 7.14 (t, J=5.0 Hz, 1H); ^{13}CNMR (125 MHz, $CDCl_3$): δ (ppm) 14.73, 19.42, 27.49, 29.89, 32.98, 37.03, 40.88, 51.30, 55.41, 60.20, 105.97, 111.29, 111.66, 114.66, 120.96, 129.17, 144.81, 149.33, 150.69, 159.73, 168.10.

Ethyl 1,4,5,6,7,8-hexahydro-4-(2-methoxyphenyl)-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate (12).

White solid; melting point: 251-253°C; IR (KBr): 3285, 2957, 1689, 1611, 1488, 1381, 1216 cm^{-1}; 1H NMR (400 MHz, DMSO-d6): δ (ppm) 0.83 (s, 3H), 0.99 (s, 3H), 1.10 (t, J =7.08 Hz, 3H), 1.89 (d, J =16.08 Hz, 1H), 2.11 (d, J =16.08 Hz, 1H), 2.18 (s, 3H), 2.40-2.50 (Distorted AB system, 2H), 3.68 (s, 3H), 3.91 (q, J =3.64 Hz, 2H), 5.04 (s, 1H), 6.75 (d, J =7.44 Hz, 1H), 6.82 (d, J =8.04 Hz, 1H), 7.03 (d, J =7.36 Hz, 1H), 7.09 (q, J =1.44 Hz, 1H), 8.93 (s, 1H); 13C NMR (100 MHz, DMSO-d6): δ (ppm) 14.05, 18.00, 26.15, 29.28, 31.95, 32.77, 50.36, 55.14, 58.72, 102.89, 108.64, 110.96, 119.44, 126.90, 130.46, 134.93, 144.08, 149.94, 157.10, 167.26, 193.79.

Ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-4-(naphtalene-1-yl)-5-oxoquinoline-3-carboxylate (13).

White solid; melting point: 232-233°C; IR (KBr): 3291, 3071, 2936, 1700, 1639, 1604, 1486, 1377, 1276, 1211 cm^{-1}. 1H NMR: (400 MHz, CDCl3): δ (ppm) 0.89 (t, J =8.8 Hz, 3H), 1.04 (s, 3H), 2.04 (s, 3H), 2.09 (d, J =13.6 Hz, 1H), 2.16 (s, 1H), 2.21 (d, J =9.6 Hz, 1H), 2.26 (s, 1H), 2.36 (s, 3H), 3.75- 3.96 (m, 2H), 5.83 (s, 1H), 6.19 (s, 1H), 7.28 (s, 1H), 7.34 (t, J =7.6 Hz, 1H), 7.434 (t, J = 7.6 Hz, 1H), 7.56 (t, J = 7.6 Hz, 1H), 7.63 (d, J = 8 Hz, 1H), 7.75 (d, J = 8 Hz, 1H), 8.82 (d, J = 8.8 Hz, 1H); 13C NMR (100 MHz, CDCl3): δ (ppm) 13.9, 19.3, 27.1, 29.3, 31.7, 32.5, 41.0, 50.5, 59.6, 107.8, 113.4, 125.2, 125.8, 126.6, 126.8, 127.7, 131.1, 133.2, 142.7, 146.0, 147.6, 167.5, 195.6.

Ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxo-4-(thiophen-2-yl)XXXuinolone-3-carboxylate (14).

White solid; melting point: 242-243˚C; IR (KBr): 3285, 3080, 2963, 1696, 1643, 1611, 1487, 1282, 1211; ^{1}HNMR (500 MHz, $CDCl_3$): δ (ppm) 1.06 (s,3H), 1.13 (s,3H), 1.29 (t, J=5.0 Hz, 3H), 2.26 (s,1H), 2.29 (s, 2H), 2.37 (s, 1H), 2.41 (s,3H), 4.16-4.21 (m, 2H), 5.45 (s, 1H), 6.27 (s,1H), 6.87 (s, 2H), 7.06 (d, J=5.0 Hz, 1H); ^{13}CNMR (125 MHz, $CDCl_3$): δ (ppm) 14.75, 19.65, 27.66, 29.98, 31.68, 33.089, 41.16, 51.19, 60.38, 105.73, 111.69, 123.48, 123.78, 126.84, 144.84, 149.89, 151.55, 167.73.

Ethyl 4-(furan-2-yl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate (15).

White solid; melting point: 246–248˚C; IR (KBr): 3285, 3219, 3083, 2964, 1677, 1606, 1488, 1321, 1218.

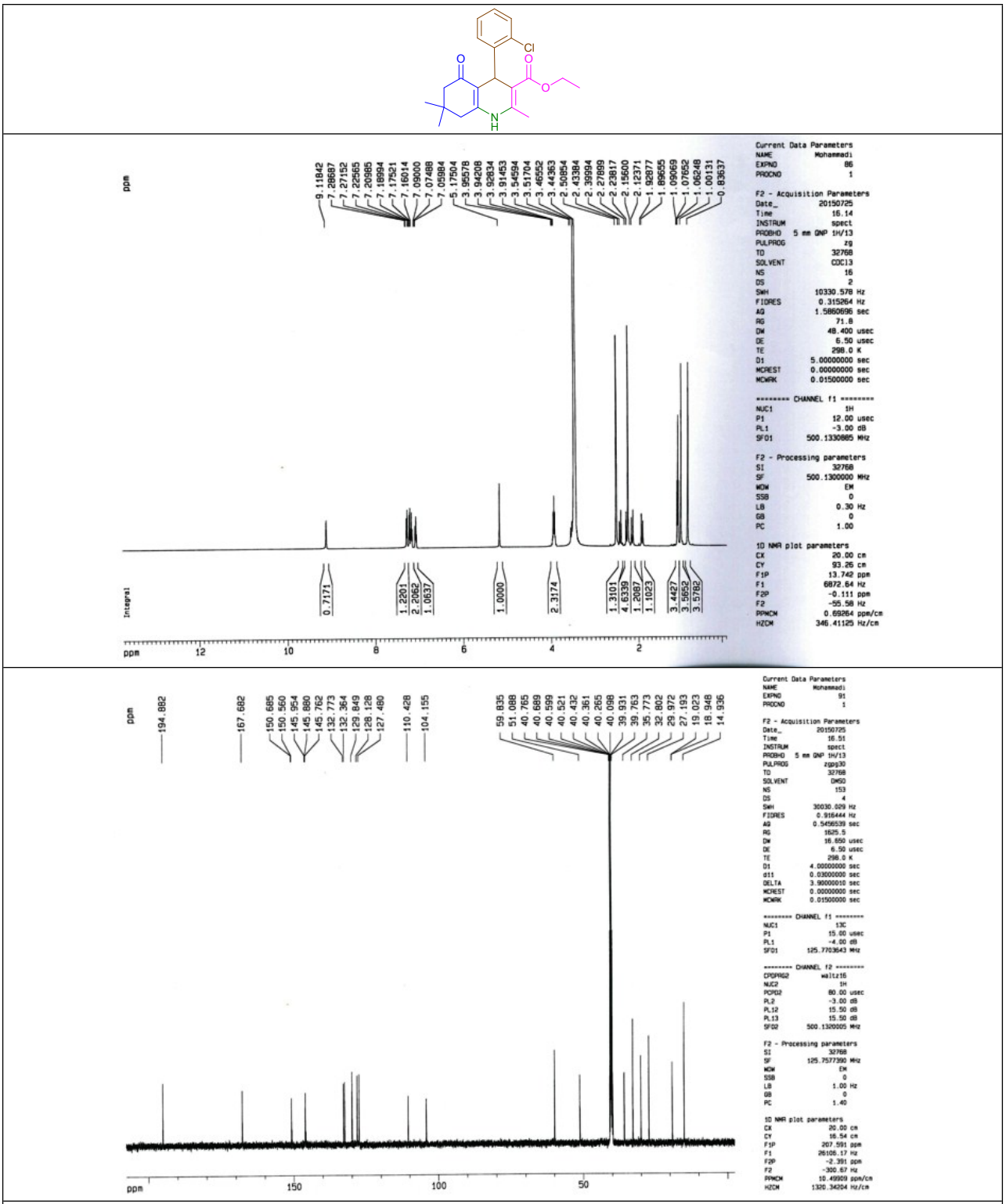

Fig. 10 HNMR and CNMR spectra of 4-(2-chlorophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

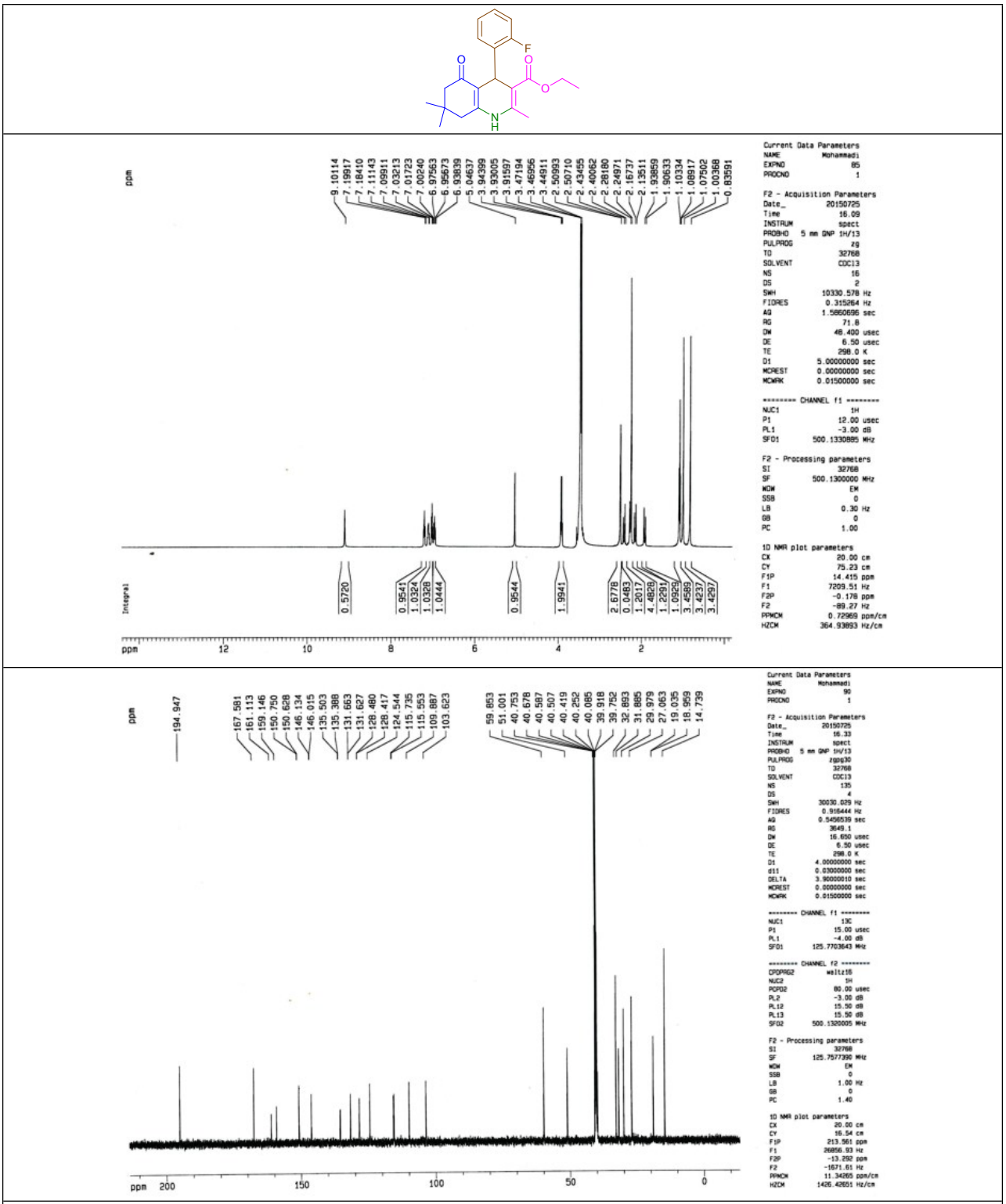

Fig. 11 HNMR and CNMR spectra of 4-(2-fluorophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

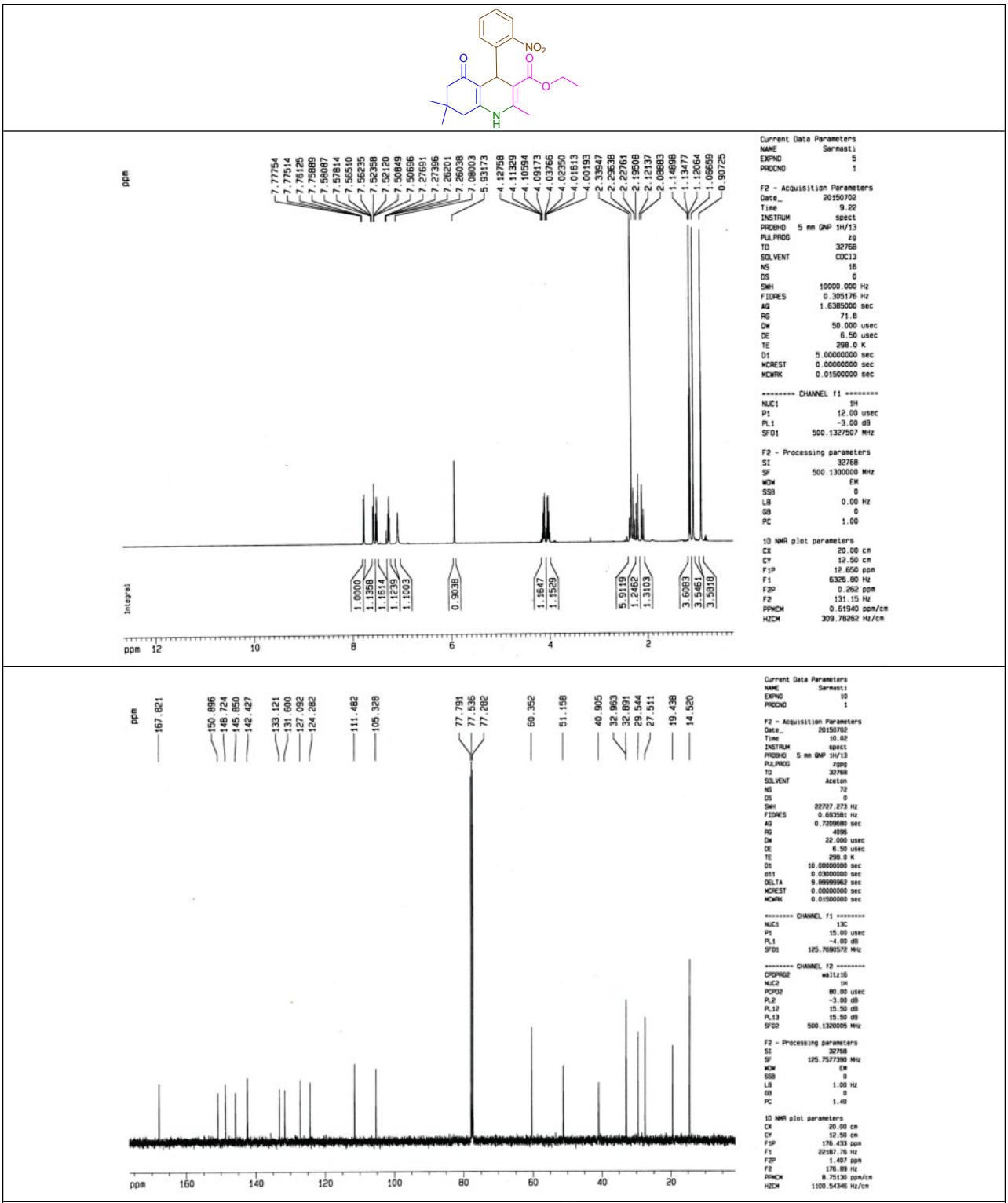

Fig. 12 HNMR and CNMR spectra of Ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-4-(2-nitrophenyl)-5-oxoquinoline-3-carboxylate

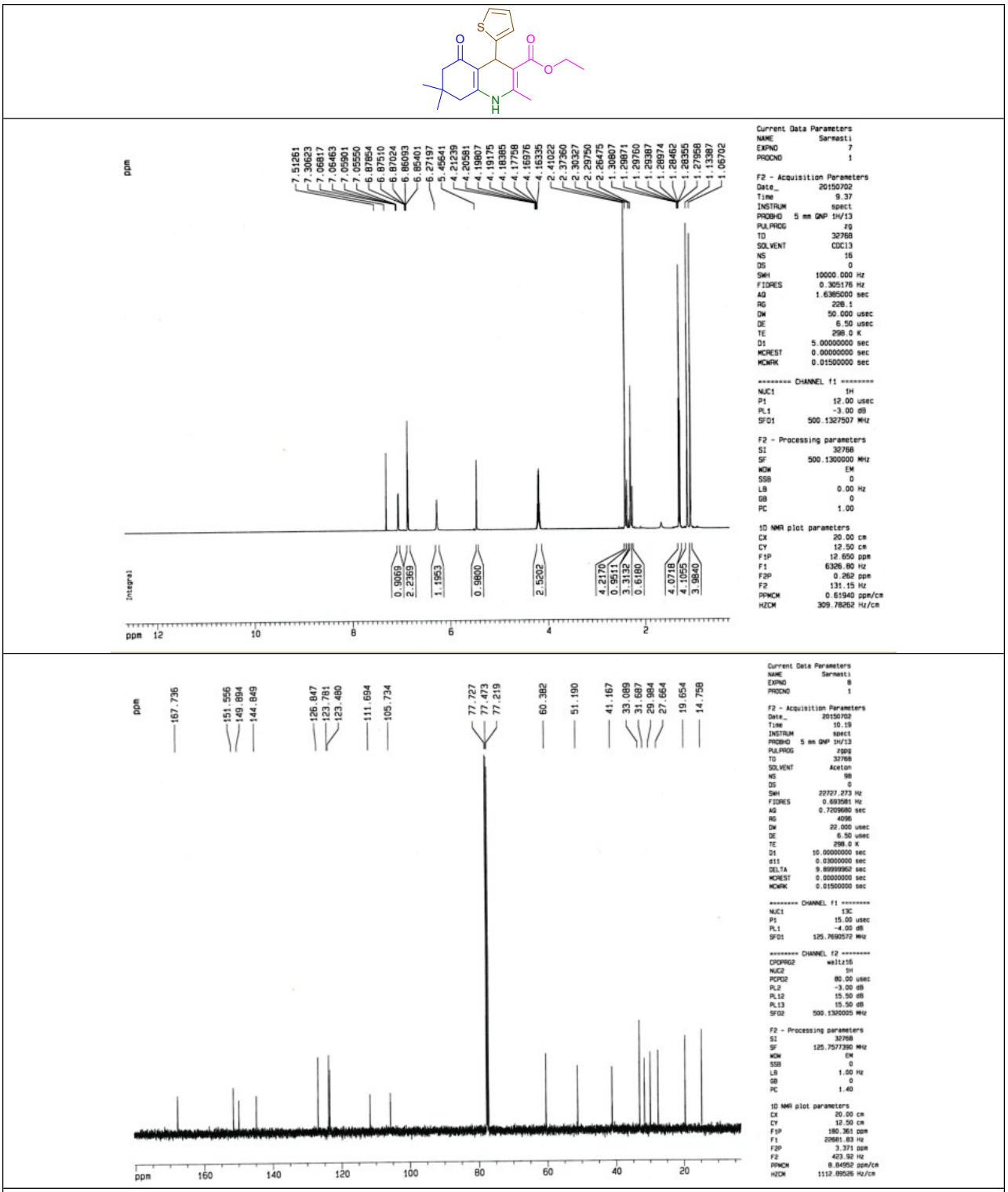

Fig. 13 HNMR and CNMR spectra of Ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxo-4-(thiophen-2-yl)XXXuinolone-3-carboxylate

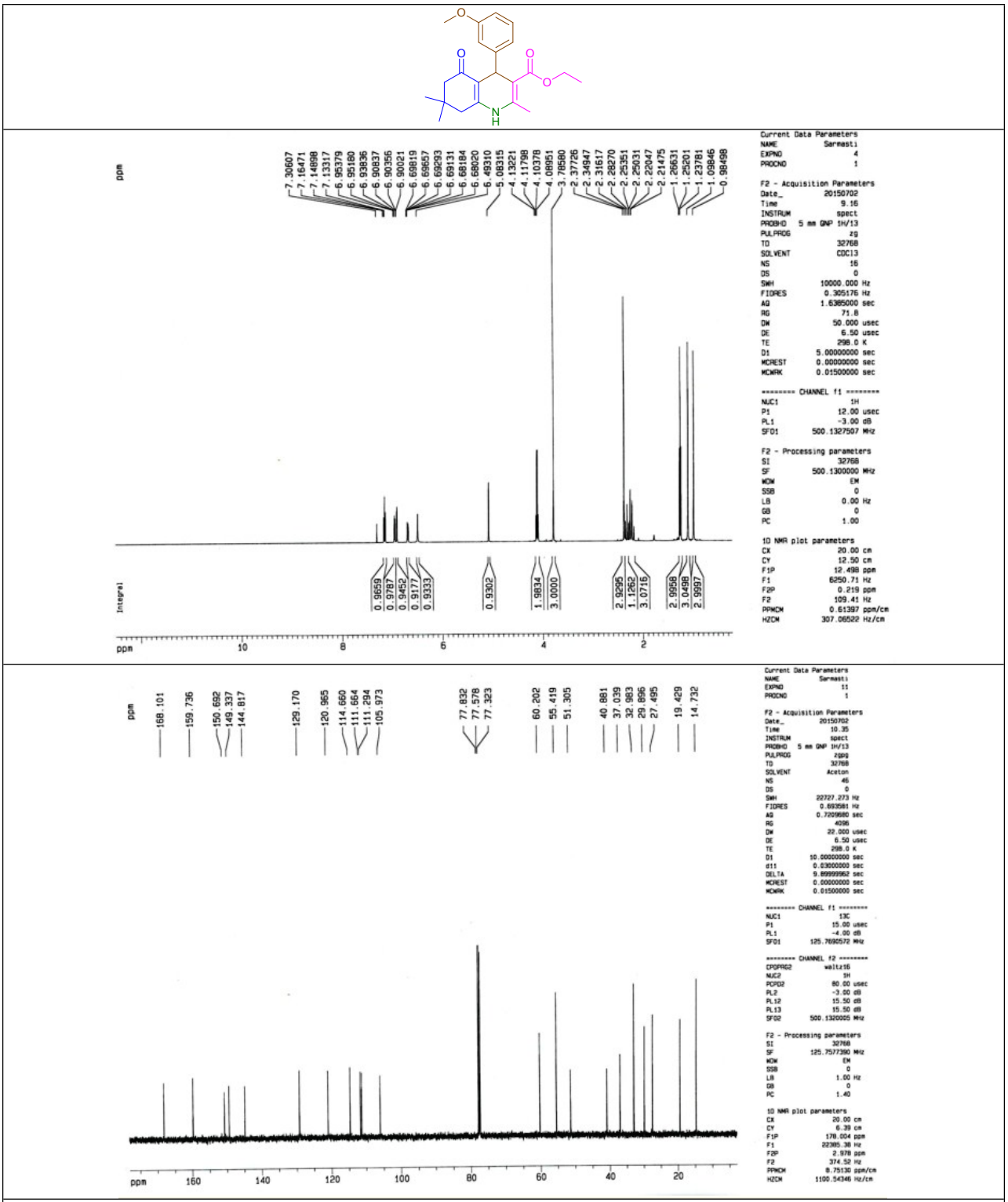

Fig. 14 HNMR and CNMR spectra of Ethyl 1,4,5,6,7,8-hexahydro-4-(3-methoxyphenyl)-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

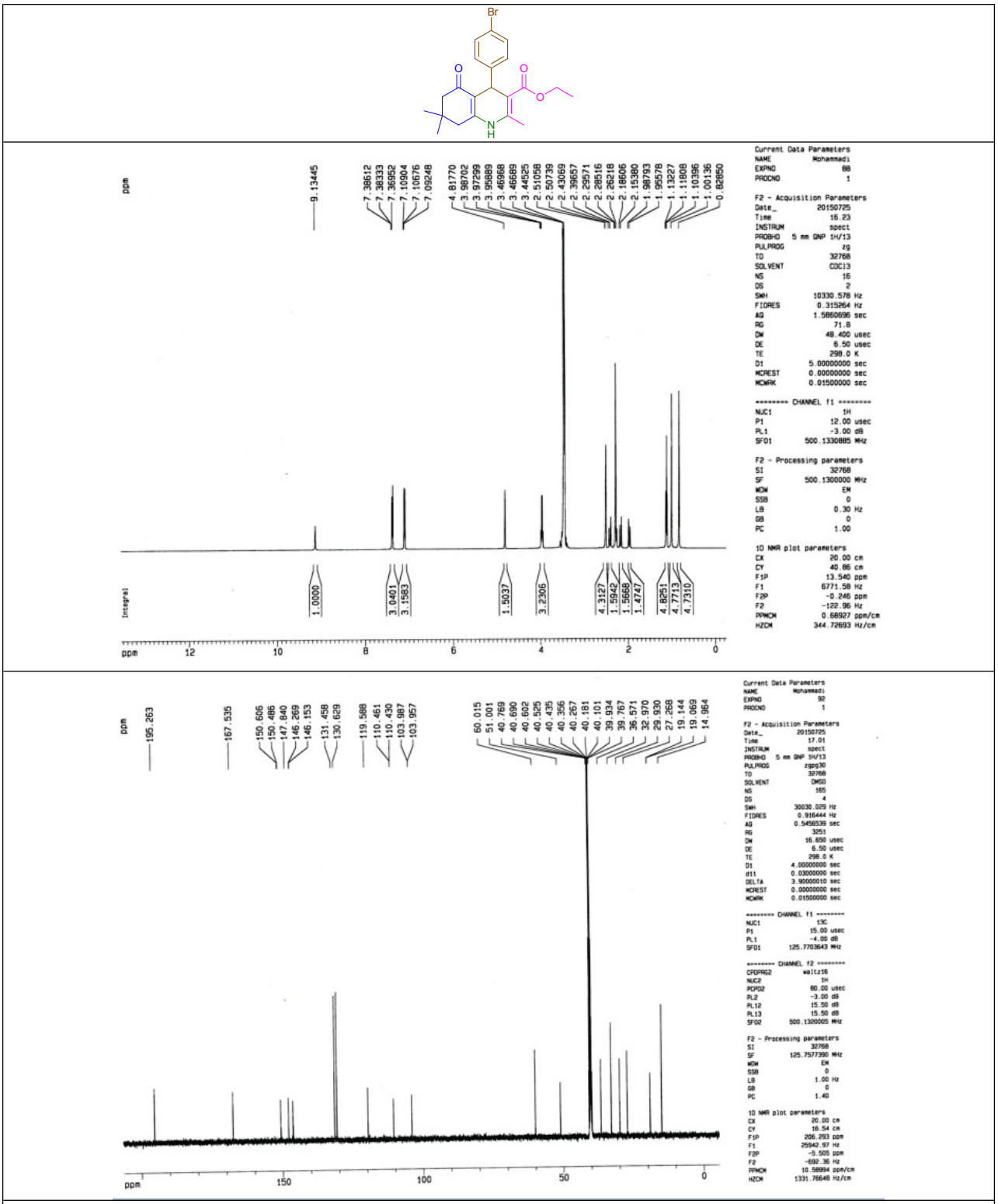

Fig. 15 HNMR and CNMR spectra of Ethyl 4-(4-bromophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

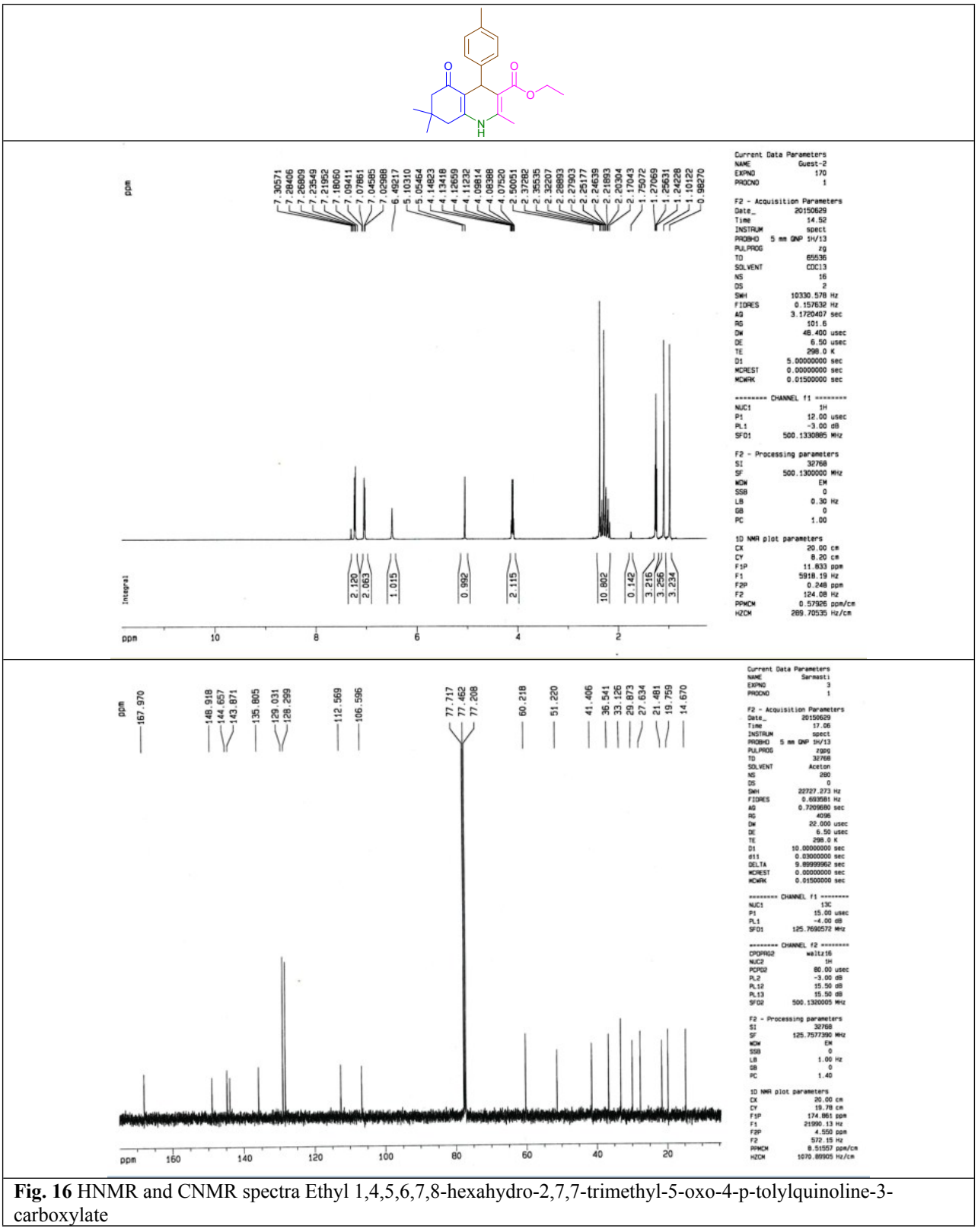

Fig. 16 HNMR and CNMR spectra Ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxo-4-p-tolylquinoline-3-carboxylate

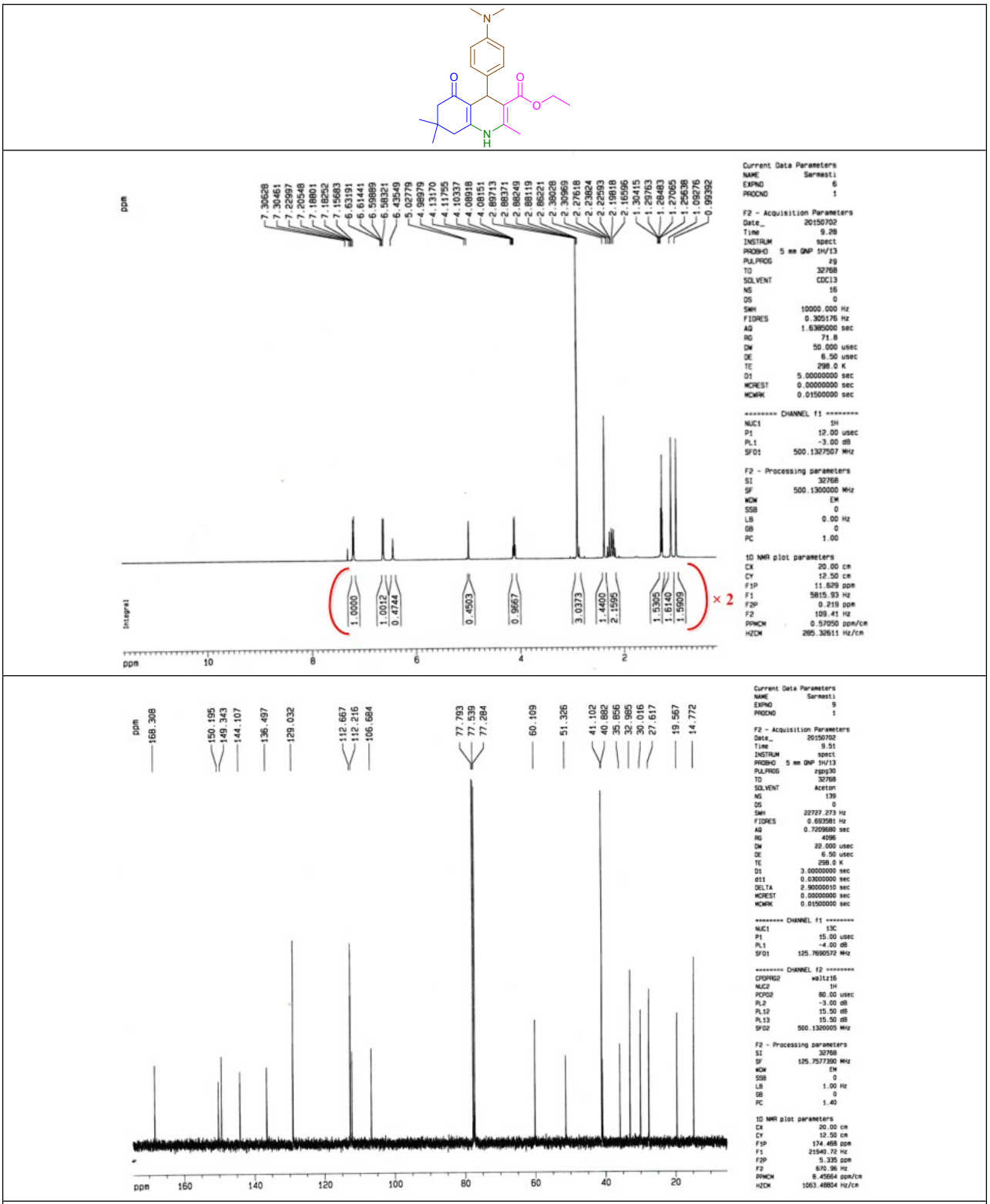

Fig. 17 HNMR and CNMR spectra of Ethyl 4-(4-(dimethylamino) phenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate