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Iodine-catalyzed addition of 2-mercaptoethanol to chalcone derivatives: Synthesis of the novel β-mercapto carbonyl compounds

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Abstract: In this study, a series of novel β-mercapto carbonyl derivatives (3-(2-hydroxyethylthio)-1,3-diarylpropan-1-one) (**5a-i**) were prepared by addition of 2-mercaptoethanol (**4**) to chalcones (**3a-i**) in the presence of catalytic amount of iodine (10 mol %) in CH_2Cl_2.

Keywords: Chalcone; 2-mercaptoethanol; iodine; Thia-michael addition; β-mercapto carbonyl.

1. Introduction

Sulfur-containing compounds are known to exhibit various biological activities, such as antibacterial,[1-3] antimicrobial,[4] antifungal,[5,6] anticancer,[7,8] anti-thrombotic, antioxidant, anti-diabetic effects[9] and potential cytotoxic agent.[10] Also, β-mercapto carbonyl derivatives are used for the synthesis of various biologically active compounds such as thiochromans,[11,12] thiapyrans,[13] benzothiazapines,[14,15] 4,5-dihydropyrazoles,[16] etc.

Thia-Michael addition reaction is one of the most fundamental C-S bond-forming reactions in the synthesis of β-mercapto carbonyl derivatives which have valuable synthetic scaffolds for biological, medicinal and synthetic organic chemists. Conjugate addition of sulfur-centered nucleophiles to α,β-unsaturated carbonyls such as chalcones serves a powerful synthetic method in this area of sulfur chemistry.[17-19]

Traditionally, the 1,4-addition of thiols is catalyzed by strong bases such as alkali metal alkoxides,[20-22] hydroxides, and amines.[23,24] On the other hand, these reactions were also investigated using solid acids such as $HClO_4$-SiO_2[25] and different Lewis acids such as $InBr_3$,[26] $Zn(ClO_4)_2.6H_2O$,[27] $Hf(OTf)_3$,[28] $Bi(NO_3)_3$,[29] $Bi(OTf)_3$,[30] and $Cu(BF_4)_2$,[17] ionic liquid [pmIm]Br,[31,32] and organocatalyst in solvent-free conditions.[33]

Most of the methods have some disadvantages such as long reaction times, high reaction temperatures, dry or stringent reaction conditions, complex workup procedures, and moderate yields.

Previously, molecular iodine has used as a efficiently catalyst for addition of thiols to α,β-unsaturated carbonyl compounds. For example, Yao et al.[34,35] have reported the iodine catalyzed addition of mercaptans (such as PhSH and RSH) to α,β-unsaturated ketones and -acids. In addition, in our recently studies, we have reported the molecular iodine catalyzed addition of thiophenol and methyl thioglycolate[36,37] to chalcone derivatives.

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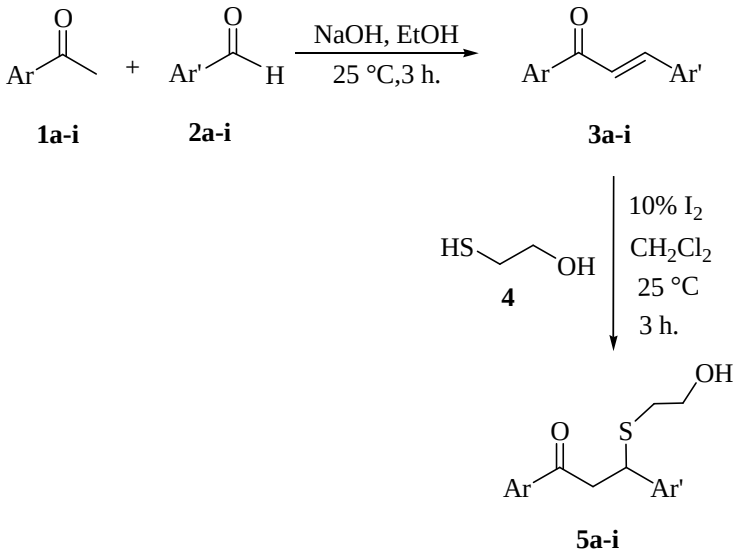
Although, there are many researches related to the conjugate addition of thiols to α,β-unsaturated carbonyl compounds in the literature, one compound[38] is known obtained from $Yb(OTf)_3$ catalyzed addition of 2-mercaptoethanol to chalcone derivative ((E)-1-(4-chlorophenyl)-3-phenylprop-2-en-1-one) according to the our literature surveys. For this reason, in this paper, we report to the addition of 2-mercaptoethanol to some chalcone derivatives, and molecular iodine was used as a catalyst.

2. Results and discussion

Synthesis of chalcone derivatives (**3a-i**) were carried out through Claisen-Schmidt condensation[39-43] of substituted acetophenones and 2-furyl methyl ketone with the substituted benzaldehydes and thiophene-2-carbaldehyde using sodium hydroxide as catalyst in ethanol at room temperature in high yields (>80%). The structures of chalcones (**3a-i**) were elucidated by spectroscopic methods and by comparison authentic samples (3a-3[41], 3g[42], 3h[42]).

First, the addition of 2-mercaptoethanol with chalcone was explored to detect the optimum conditions, such as catalysts and solvent. The reaction gave the low yields of when it was carried out in alkali ethanol, alkali methanol and solid I_2 in ethanol. A longer reaction time would be necessary and lower yield was obtained with CH_2Cl_2 and solid I_2. The best results were obtained using the dissolved I_2 in CH_2Cl_2 for about 4 hours at room temperature.

The reaction of chalcone derivatives (**3a-i**) with 2-mercaptoethanol (**4**) and solution of 10% mol dissolved iodine in CH_2Cl_2 at room temperature for 4 hours gave selectively **5a-i** by the chemoselective addition of a thiol group (Scheme, Table). The crude products were purified by crystallization in CCl_4/*n*-hexane (1:3) and obtained in 67%-86% isolated yields.



Scheme 1. Synthesis of 3-(2-hydroxyethylthio)-1,3-diarylpropan-1-one (**5a-i**)

The compounds (**5a-i**) have been characterized by IR, ^{1}H and ^{13}C NMR and elemental analyze data. The ^{1}H-NMR spectrum of **5a-i** showed two AB systems (that is characteristic to these compounds[43]) led to the protons of $-CH_2\underline{CH_2}OH$ (δ 3.80-3.71 and 3.67-3.62 as doublet of doublet of triplet as if multiplet of doublet) and $PhCO\underline{CH_2}$ (δ 3.58-3.53 doublet of doublet J = 17.6-17.2 Hz and δ 3.49-3.43 doublet of doublet J = 7.6-6.8 Hz), respectively. The protons of $PhCOCH_2\underline{CH}$ of **5a-i** appeared as a triplet

at δ = 4.93-4.56 (J = 7.2-5.6 Hz). Addition, the protons of –S$\underline{CH_2}CH_2$ of **5a-i** appeared as a triplet at δ = 2.59-2.55 (J = 6.4-5.6 Hz). All of the spectral data are consistent with the proposed compounds.

Table 1. Iodine-catalyzed synthesized compounds **3a-ı**

Entry	Ar	Ar'	Product	Yield (%)[a]
1	Ph	3-Cl-C_6H_4	**5a**	85
2	Ph	4-Cl-C_6H_4	**5b**	70
3	Ph	4-CH_3O-C_6H_4	**5c**	82
4	4-Br-C_6H_4	Ph	**5d**	70
5	4-Cl-C_6H_4	4-Cl-C_6H_4	**5e**	86
6	4-CH_3-C_6H_4	4-CH_3-C_6H_4	**5f**	71
7	4-CH_3O-C_6H_4	4-CH_3O-C_6H_4	**5g**	71
8	2-OH-C_6H_4	2-thienyl	**5h**	75
9	2-thienyl	2-thienyl	**5i**	67

a) Isolated yields

3. Conclusion

Summary, a series of novel β-mercapto carbonyl derivatives (3-(2-hydroxyethylthio)-1,3-diarylpropan-1-one) (**5a-i**) were prepared by iodine-catalyzed addition of 2-mercaptoethanol (**4**) to chalcones (**3a-i**) at room temperature for 4 hours. The structures of synthesized compounds were elucidated by spectroscopic methods (IR, ^{1}H-, ^{13}C-NMR and Elemental analysis).

4. Experimental

Melting points were measured on Electrothermal 9100 apparatus. IR spectrums (KCl disc) were recorded on a Jasco FT/IR-430 spectrometer. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker Avance DPX-400 instrument. As internal standards served TMS (δ 0.00) for ^{1}H NMR and $CDCl_3$ (δ 77.0) for ^{13}C NMR spectroscopy J values are given in Hz. The multiplicities of the signals in the ^{1}H NMR spectra are abbreviated by s (singlet), d (doublet), t (triplet), q (quarted), m (multiplet), br (broad) and combinations thereof. Elemental analyses were obtained from a LECO CHNS 932 Elemental Analyzer.

General procedure for the synthesis of chalcone derivatives 3:

Chalcone derivatives (**3a-ı**) were synthesized by known method [27]. To a solution of a acetophenone derivative (1 mmol) in EtOH (20 ml) was added the related aromatic aldehyde derivative (1 mmol) and NaOH (2.5 M, 8 ml) at r.t. The mixture was stirred for 3 h, neutralized with diluted HCl, and extracted with $CHCl_3$. The organic layer was dried (Na_2SO_4) and evaporated. The residue was purified by crystallized in $CHCl_3$/hexane (3:7).

1,3-dip-tolylprop-2-en-1-one (3f): Yield 84%; yellow crystal; mp 125 - 128 ºC. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 7.96 (d, J = 6.4 Hz), 7.56 (m, 3H, 2ArH, α-H), 7.83 (d, J = 5.6 Hz, β-H), 7.33 (d, J = 4.4 Hz), 7.25 (d, J = 4.4 Hz), 2.45 (s, 3H), δ = 2.41(s, 3H). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 190.1, 144.5, 143.5, 140.9, 135.7, 132.3, 129.7 (2C), 129.3 (2C), 128.6 (2C), 128.5 (2C), 121.1, 21.7, 21.6. IR (KCl, cm^{-1}): 3413, 3027, 2915, 1922, 1731, 1563, 1411, 1378, 1307, 1284, 1201, 1114, 850, 827, 676, 599. *Anal*. Calcd for: $C_{17}H_{16}O$: C, 86.40; H, 6.82. Found: C, 86.69; H, 6.62.

1,3-di(thiophen-2-yl)prop-2-en-1-one (3i): Yield 94%; yellow crystal; mp 93-96 ºC. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 7.98 (d, *J* = 15.2 Hz, 1H), 7.85 (dd, *J* = 3.6 Hz, 1.0 Hz, 1H), 7.68 (dd, *J* = 5.0 Hz, 1.0 Hz, 1H), 7.43 (brd, *J* = 5.2 Hz, 1H), 7.37 (brd, *J* = 3.6 Hz, 1H), 7.22 (d, *J* = 15.2 Hz, 1H), 7.18 (dd, *J* = 4.8 Hz, 4.0 Hz, 1H), 7.10 (dd, *J* = 5.2 Hz, 3.6 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 181.6, 145.5, 140.1, 136.5, 133.9, 132.2, 131.7, 128.9, 128.4, 128.3, 120.4. IR (KCl, cm^{-1}): 3118, 3091, 1635, 1571, 1515, 1407, 1282, 1214, 971, 827, 721, 588. *Anal*. Calcd for: $C_{11}H_8OS_2$: C, 59.97; H, 3.66; S, 29.11. Found: C, 60.09; H, 3.72; S, 29.55.

General procedure for the synthesis of 5:

To a solution of chalcone derivative (1 equv.) and 2-mercaptoethanol (1.5 equv.) in dichloromethane (15 mL) was added the solution of iodine (10% mole) in dichloromethane (1 mL) and the mixture was stirred at room temperature for 3 hours. Then, iodine removed with diluted $Na_2S_2O_3$ solution and washed with H_2O. The organic layer was dried over Na_2SO_4 and the solvent removed in reduced pressure. The crude product was purified on by crystallized in CCl_4/*n*-hexane (1:3).

3-(3-Chlorophenyl)-3-(2-hydroxyethylthio)-1-phenylpropan-1-one (5a): Yield 85%; white crystal; mp 68-70 ºC. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 7.93 (d, *J* = 7.6 Hz, 2H, ArH), 7.58 (t, *J* = 7.2 Hz, 1H, ArH), 7.46 (quasi t, *J* = 7.6 Hz, 3H, ArH), 7.34-7.21 (m, 3H, ArH), 4.59 (t, *J* = 7.2 Hz, 1H, -CH), 3.76-3.67 (dm, 2H, -$\underline{CH_2}$OH), 3.58 (dd, *J* = 17.6, 7.2 Hz, 1H, -CO$\underline{CH_2}$), 3.48 (dd, *J* = 17.6, 6.8 Hz, 1H, -CO$\underline{CH_2}$), 2.78 (bs, 1H, -OH), 2.59 (t, *J* = 6.0 Hz, 2H, -S$\underline{CH_2}$-). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 196.6, 144.4, 136.4, 134.5, 133.6, 129.9, 128.7 (2C), 128.1 (2C), 127.9, 127.7, 126.2, 60.8, 45.3, 43.4, 34.5. IR (KCl, cm^{-1}): 3280, 3052, 2919, 2896, 2865, 1683, 1590, 1569, 1446, 1409, 1224, 1062, 979, 755, 732, 686, 634. *Anal*. Calcd for: $C_{17}H_{17}ClO_2S$: C, 63.64; H, 5.34; S, 9.99. Found: C, 63.69; H, 5.62; S, 10.08.

3-(4-Chlorophenyl)-3-(2-hydroxyethylthio)-1-phenylpropan-1-one (5b): Yield 70%; white crystal; mp 59-62 ºC. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 7.93 (d, *J* = 8.8 Hz, 2H, ArH), 7.59 (t, *J* = 7.2 Hz, 1H, ArH), 7.47 (t, *J* = 8.0 Hz, 2H, ArH), 7.39 (d, *J* = 8.4 Hz, 2H, ArH), 7.30 (d, J = 8.4 Hz, ArH, 2H), 4.61 (t, *J* = 7.2 Hz, 1H, -CH), 3.77-3.66 (dm, 2H, -$\underline{CH_2}$OH), 3.57 (dd, *J* = 17.4, 7.0 Hz, 1H, -CO$\underline{CH_2}$), 3.48 (dd, *J* = 17.2, 6.8 Hz, 1H, -CO$\underline{CH_2}$), 2.65 (bs, 1H, -OH), 2.58 (t, *J* = 6.4 Hz, 2H, -S$\underline{CH_2}$-). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 196.7, 140.7, 136.5, 133.5, 133.1, 129.2 (2C), 128.8 (2C), 128.7 (2C), 128.1, 60.8, 45.3, 43.2, 34.5. IR (KCl, cm^{-1}) **:** 3234, 2948, 2910, 2877, 1677, 1594, 1492, 1450, 1421, 1330, 1224, 1045, 1012, 975, 759, 692 (Şekil 29). *Anal*. Calcd for: $C_{17}H_{17}ClO_2S$: C, 63.64; H, 5.34; S, 9.99. Found: C, 63.78; H, 5.58; S, 10.18.

3-(2-Hydroxyethylthio)-3-(4-methoxyphenyl)-1-phenylpropan-1-one (5c): Yield 82%; white crystal; mp 69-71 ºC. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 7.94 (d, *J* = 7.2 Hz, 2H, ArH), 7.59 (t, *J* = 7.2 Hz, 1H, ArH), 7.48 (t, *J* = 7.6 Hz, 2H, ArH), 7.52 (d, *J* = 8.8 Hz, 2H, ArH), 6.87 (d, *J* = 8.8 Hz, 2H, ArH), 4.59 (t, *J* = 7.0 Hz, 1H, -CH), 3.80 (s, 3H, -OCH_3), 3.74-3.62 (dm, 2H, -$\underline{CH_2}$OH), 3.57 (dd, *J* = 17.6, 7.2 Hz, 1H, -CO$\underline{CH_2}$), 3.49 (dd, *J* = 17.6, 6.8 Hz, 1H, -CO$\underline{CH_2}$), 2.59 (t, *J* = 6.0 Hz, 2H, -S$\underline{CH_2}$-), 2.43 (bs, 1H, -OH). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 197.1, 158.9, 136.68, 133.9, 133.4, 128.9 (2C), 128.7 (2C), 128.1 (2C), 114.1 (2C), 60.6, 55.3, 45.6, 43.2, 34.3. IR (KCl, cm^{-1}): 3445, 3060, 2965, 2931, 2838, 1668, 1604, 1573, 1508, 1454, 1421, 1338, 1257, 1236, 1174, 985, 700 (Şekil 32). *Anal*. Calcd for: $C_{17}H_{17}ClO_2S$: C, 68.33; H, 6.37; S, 10.13. Found: C, 68.45; H, 6.27; S, 10.44.

1-(4-Bromophenyl)-3-(2-hydroxyethylthio)-3-phenylpropan-1-one (5d): Yield 70%; white crystal; mp 69-72 ºC. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 7.77 (d, *J* = 8.0 Hz, 2H, ArH), 7.57 (d, *J* = 8.0 Hz, 2H, ArH), 7.42 (d, *J* = 7.2 Hz, 2H, ArH), 7.33 (d, *J* = 7.2 Hz, 2H, ArH), 7.25 (m, 1H, ArH), 4.59 (t, *J* = 6.8 Hz, 1H, -CH), 3.78-3.62 (dm, 2H, -$\underline{CH_2}$OH), 3.55 (dd, *J* = 17.4, 7.2 Hz, 1H, -CO$\underline{CH_2}$), 3.46 (dd, *J* = 17.4, 6.6 Hz, 1H, -CO$\underline{CH_2}$), 2.82 (bs, 1H, -OH), 2.58 (t, *J* = 5.6 Hz, 2H, -S$\underline{CH_2}$-). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 196.1, 141.9, 135.3, 132.0, 131.9 (2C), 129.6 (2C), 128.8 (2C), 127.8 (2C), 127.6, 60.7, 45.4, 34.5, 30.3. IR (KCl, cm^{-1}): 3417, 2948, 2913, 2859, 1673, 1583, 1419, 1394, 1334, 1282, 1064, 1052, 985, 825, 700, 435. *Anal*. Calcd for: $C_{17}H_{17}BrO_2S$: C, 55.90; H, 4.69; S, 8.78. Found: C, 55.79; H, 5.62; S, 9.08.

1,3-Bis(4-chlorophenyl)-3-(2-hydroxyethylthio)propan-1-one (5e): Yield 86%; white crystal; mp 150-153 ^{o}C. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 7.85 (d, *J* = 8.4 Hz, 2H, ArH), 7.42 (d, *J* = 8.4 Hz, 2H, ArH), 7.37 (d, *J* = 8.4 Hz, 2H, ArH), 7.29 (d, *J* = 8.4 Hz, 2H, ArH), 4.58 (t, *J* = 7.2 Hz, 1H, -CH), 3.76-3.65 (dm, 2H, -$\underline{CH_2}$OH), 3.53 (dd, *J* = 17.6, 7.2 Hz, 1H, -CO$\underline{CH_2}$), 3.43 (dd, *J* = 17.6, 6.8 Hz, 1H, -CO$\underline{CH_2}$), 2.65 (bs, 1H, -OH), 2.57 (t, *J* = 6.0 Hz, 2H, -S$\underline{CH_2}$-). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 195.5, 140.5, 140.0, 134.7, 133.2, 129.5 (2C), 129.2 (2C), 129.0 (2C), 128.8 (2C), 60.7, 45.3, 43.2, 34.5. IR (KCl, cm^{-1}): 3390, 2952, 2919, 2883, 1675, 1589, 1492, 1423, 1326, 1218, 1093, 1012, 997, 981, 817, 651, 507. *Anal*. Calcd for: $C_{17}H_{16}Cl_2O_2S$: C, 57.47; H, 4.54; S, 9.03. Found: C, 57.69; H, 5.62; S, 9.38.

3-(2-Hydroxyethylthio)-1,3-dip-tolylpropan-1-one (5f): Yield 71%; white crystal; mp 52-55 ^{o}C. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 7.85 (d, *J* = 8.4 Hz, 2H, ArH), 7.34(d, *J* = 8.0 Hz, 2H, ArH), 7.25(d, *J* = 8.4 Hz, 2H, ArH), 7.15 (d, *J* = 8.4 Hz, 2H, ArH), 4.60 (t, *J* = 7.2 Hz, 1H, -CH), 3.74-3.64 (dm, 2H, -$\underline{CH_2}$OH), 3.56 (dd, *J* = 17.2, 7.6 Hz, 1H, -CO$\underline{CH_2}$), 3.48 (dd, *J* = 17.2, 6.8 Hz, 1H, -CO$\underline{CH_2}$), 2.93 (bs, 1H, -OH), 2.59 (t, *J* = 5.6 Hz, 2H, -S$\underline{CH_2}$-), 2.41 (s, 3H, -CH_3), 2.34 (s, 3H, -CH_3). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 196.8, 144.2, 139.1, 137.1, 134.3, 129.4 (2C), 129.3 (2C), 128.3 (2C), 127.7 (2C), 60.7, 45.3, 43.6, 34.5, 21.6, 21.1. IR (KCl, cm^{-1}): 3415, 3029, 2913, 1675, 1652, 1604, 1592, 1565, 1511, 1328, 1224, 1180, 1029, 1014, 993, 811, 732. *Anal* Calcd for: $C_{19}H_{22}O_2S$: C, 72.57; H, 7.05; S, 10.20. Found: C, 72.69; H, 7.12; S, 10.58.

3-(2-Hydroxyethylthio)-1,3-bis(4-methoxyphenyl)propan-1-one (5g): Yield 71%; white crystal; mp 79-82 ^{o}C. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 7.89 (d, *J* = 8.8 Hz, 2H, ArH), 7.32 (d, *J* = 8.8 Hz, 2H, ArH), 6.88 (t, *J* = 8.8 Hz, 2H, ArH), 6.82 (d, *J* = 8.8 Hz, 2H, ArH), 4.56 (t, *J* = 5.6 Hz, 1H, -CH), 3.81 (s, 3H, -OCH_3), 3.72 (s, 3H, -OCH_3), 3.71-3.62 (dm, 2H, -$\underline{CH_2}$OH), 3.46 (dd, *J* = 17.6, 7.2 Hz, 1H, -CO$\underline{CH_2}$), 3.43 (dd, *J* = 17.6, 6.8 Hz, 1H, -CO$\underline{CH_2}$), 3.14 (bs, 1H, -OH), 2.55 (t, *J* = 6.0 Hz, 2H, -S$\underline{CH_2}$-). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 195.7, 163.7, 158.7, 134.1, 130.5 (2C), 129.7, 128.9 (2C), 114.0 (2C), 113.8 (2C), 60.5, 55.5, 55.2, 45.1, 43.5, 34.3. IR (KCl, cm^{-1}): 3509, 2933, 2838, 1666, 1600, 1571, 1509, 1421, 1255, 1232, 1172, 1024, 1010, 977, 819, 516. *Anal*. Calcd for: $C_{19}H_{22}O_4S$: C, 65.87; H, 6.40; S, 9.26. Found: C, 65.77; H, 6.66; S, 9.44.

3-(2-Hydroxyethylthio)-1-(2-hydroxyphenyl)-3-(thiophen-2-yl)propan-1-one (5h): Yield 75%; white crystal; mp 71-74 ^{o}C. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 12 (s, 1H, -OH), 7.76 (d, *J* = 8.0 Hz, 1H), 7.50 (t, *J* = 7.8 Hz, 1H), 7.25 (d, *J* = 5.2 Hz, 1H), 7.04 (d, *J* = 3.2 Hz, 1H), 6.99 (d, *J* = 8.4 Hz, 1H), 6,95-6,91 (m, 2H) 4.93 (t, *J* = 6.8 Hz, 1H), 3.80-3.67 (dm, 2H), 3.63 (d, *J* = 6.8 Hz, 2H), 2.78-2.65 (m, 2H), 2.28 (brs, 1H, -OH). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 202.2, 162.6, 146.3, 136.9, 129.8, 126.7, 125.8, 125.1, 119.3, 119.2, 118.7, 60.8, 45.9, 39.1, 34.9. IR (KCl, cm^{-1}): 3400, 2925, 2877, 1637, 1612, 1444, 1346, 1276, 1209, 1155, 977, 752, 723, 688, 630, 592, 514. *Anal*. Calcd for: $C_{15}H_{16}O_3S_2$: C, 58.41; H, 5.23; S, 20.79. Found: C, 58.63; H, 5.52; S, 21.18.

3-(2-Hydroxyethylthio)-1,3-di(thiophen-2-yl)propan-1-one (5i): Yield 67%; white crystal; mp 53-56 ^{o}C. ^{1}H-NMR (400 MHz, $CDCl_3$, ppm): δ = 7.75 (dd, *J* = 3.8, 1.0 Hz, 1H), 7.68 (dd, *J* = 5.0, 1.0 Hz, 1H), 7.23 (dd, *J* = 5.0, 1 Hz, 1H), 7.14 (dd, *J* = 4.9, 4.0 Hz, 1H), 7.08 (d, *J* = 3.2 Hz, 1H), 6.91 (dd, *J* = 5.2, 3.6 Hz, 1H), 4.92 (t, *J* = 7.2 Hz, 1H), 3.79-3.67 (dm, 2H), 3.54 (dd, *J* = 14.4, J = 5.2 Hz, 1H), 3.49 (dd, *J* = 14.2 4.6 Hz, 1H), 2.73-2.68 (dm, 2H), 2.62 (brs, 1H, -OH). ^{13}C-NMR (100 MHz, $CDCl_3$, ppm): δ = 189.4, 146.5, 143.8, 134.5, 132.5, 128.3, 126.6, 125.7, 125.0, 60.8, 47.0, 39.5, 34.9. IR (KCl, cm^{-1}): 3395, 3091, 2913, 2873, 1644, 1517, 1411, 1355, 1272, 1238, 1060, 1043, 848, 835, 728, 707, 592. *Anal*. Calcd for: $C_{13}H_{14}O_2S_3$: C, 52.32; H, 4.73; S, 32.23. Found: C, 52.11; H, 4.63; S, 32.98.

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