Arylation of 3-heterylmethylene-5-arylfuran-2(3*H*)-thiones

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The behaviour of 3-heterylmethylene-5-arylfuran-2(3*H*)-thiones towards the Lewis acid $AlCl_3$ under Friedel–Crafts reaction conditions compared with their oxygen analogues, the furan-2(3*H*)-ones is studied. Although the later are known to undergo alkyl/oxygen ring cleavage to give resonance stabilised carbocations which can exhibit either intra- or intermolecular alkylations, furanthiones gave 1, 4-adducts with the furan ring remaining intact. This difference in behaviour is explained in terms of both electronic and steric effects.

Keywords: furan-2(3*H*)-ones, furan-2(3*H*)-thiones, 1, 4-addition, electronic and steric factors

In the last few decades, the chemistry of furan-2(3*H*)-ones had received much attention, as these compounds are considered as the precursors of a wide variety of heterocyclic systems of synthetic and biological importance.[1] In previous publications, we were interested in converting these furanones into pyrrolones,[2,3] pyrazoles,[4] pyridazinones,[5,6] oxadiazoles,[7,8] triazoles,[9,10] and isothiazole[11] derivatives.

Also, the behaviour of 3-heterylmethylene-5-arylfuran-2(3*H*)-ones **1** as alkylating agents, under Friedel–Crafts reaction conditions, has been extensively studied by our research group.

It was found that the reaction proceeds by initial attack of the Lewis acid ($AlCl_3$) on the hetero oxygen of the furanone ring, followed by alkyl–oxygen bond cleavage to give a resonance stabilised carbocation intermediate (**3**). The latter can either attack the aromatic group intramoleculary or can be attacked by solvent (Scheme 1).

The reaction of **1a** led exclusively to the formation of benzofuran derivatives,[12] but in case of **1b**, butadiene carboxylic acids were obtained[13] as the products of intermolecular reaction mode. Recently, the reaction of the indolylmethylene furanones **1c** with aluminium chloride in benzene, toluene and anisole was studied.[14] It was found that the reaction mode was affected by the nature of aryl group at position-5 of the furanone nucleus. With Ar=Ph or C_6H_4Cl(*p*-), the products of intermolecular arylation (butadienecarboxylic acids) were isolated. But when it was *p*-anisyl group, a carbazole derivative was obtained. The preference of the intramolecular pathway in the latter case was explained on the basis of the stabilisation of the intermediate carbocation **(3)** afforded by the *p*-anisyl substituent which increases its selectivity towards the formation of the more stable carbazole derivative.

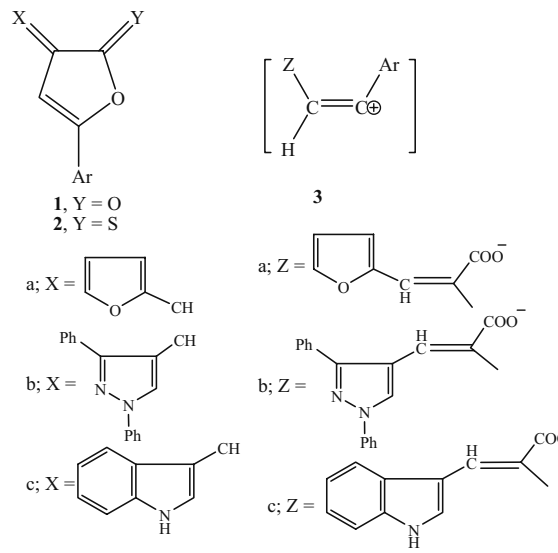
In the present investigation, we report here the results of our study on the effect of changing the carbonyl furanone by a thione group on the reaction mode.

For this purpose, the furanones **1** were converted into the thiono derivatives namely 3-heterylmethylene-5-arylfuran-2(3*H*)-thiones **2** using P_2S_5 in toluene.[15] The structure of the latter products was inferred from analytical and spectral data. The IR spectra of **2** (see Experimental) showed the disappearance of the carbonyl stretching frequency and the appearance of a band at 1250–1260 cm^{-1} attributable to the $\nu_{C=S}$ group. The ^1H NMR spectra showed signals at δ 6.51 for olefinic proton and δ 7–8 for the aromatic protons.

Furthermore, these compounds gave a positive spot test characteristic of the C=S group.[16]

When the furanthiones **2** were allowed to react with $AlCl_3$ in the presence of benzene, toluene or anisole, the products of 1, 4-addition to the α, β-unsaturated thione moiety **4–6** were obtained as the only isolable products.

The structures of **4, 5** and **6** were illustrated from: (i) analytical data corresponds to the incorporation of an aryl group in each case, (ii) the IR spectra of these products show



Scheme 1

absorption bands at 1260 cm^{-1} characteristic of the $\nu_{C=S}$, and a broad weak band at 2600 cm^{-1} attributable to the ν_{SH} of the thiol tautomer. The ^1H NMR and mass spectral data (see Experimental) confirm their structures. The formation of **4–6** is represented in Scheme 2.

This comparative study, clearly reveals that changing the carbonyl group of furan-2(3*H*)-ones by a thiono group, led the reaction with $AlCl_3$ under Friedel–Crafts reaction conditions, to follow a completely different course.

We believe that this difference of behaviour can be explained in terms of electronic and steric factors:

Electronic factor

The thiono group (C=S) is more polarisable compared with the carbonyl group due to the d-orbitals of the sulfur atom. The later therefore possesses high electron density and becomes more susceptible to attack by the Lewis acid. We have performed a b3lyp/6-31 G(d) method[17] to account for the favoured complexation between C=S and $AlCl_3$ compared with the corresponding C=O group. The charge on $AlCl_3$ moiety on approach to C=S has been found –0.34 a.u. On the other hand, the value in case of C=O was found –0.3 a.u which confirmed the tendency of C=S to form a complex with $AlCl_3$.

Steric factor

The thiono group being more bulky than the carbonyl group might exert some steric hinderence on the approach and hence

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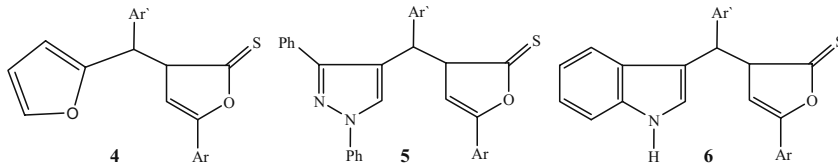
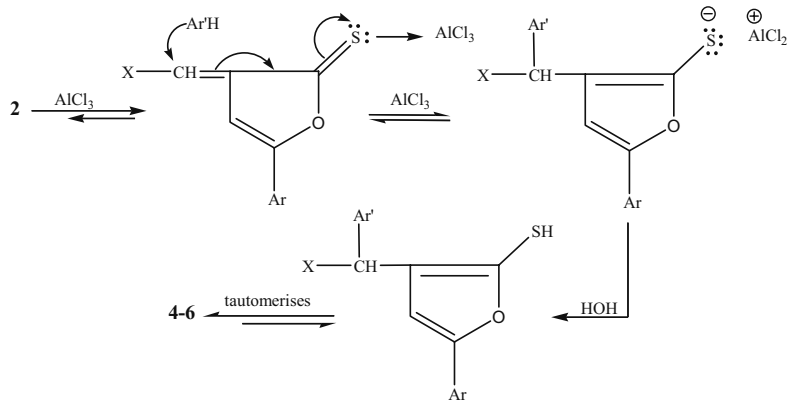


4 **5** **6**

a; Ar = C_6H_5- , Ar' = C_6H_5-
b; Ar = C_6H_5- , Ar' = $C_6H_4CH_3$(p-)
c; Ar = C_6H_5- , Ar' = $C_6H_4OCH_3$(p-)
d; Ar = C_6H_4Cl(p)- , Ar' = C_6H_5-
e; Ar = C_6H_4Cl(p)- , Ar' = $C_6H_4CH_3$(p-)
f; Ar = C_6H_4Cl(p)- , Ar' = $C_6H_4OCH_3$(p-)
g; Ar = $C_6H_4OCH_3$(p-) , Ar' = C_6H_5-
h; Ar = $C_6H_4OCH_3$(p-) , Ar' = $C_6H_4CH_3$(p-)
i; Ar = $C_6H_4OCH_3$(p-) , Ar' = $C_6H_4OCH_3$(p-)



Scheme 2

the attack of the bulky Lewis acid ($AlCl_3$) on the nearbly hetero oxygen.

Experimental

Melting points were measured on an electrothermal melting point apparatus. Elemental analyses were carried out at the Microanalytical unit, Cairo University. IR spectra were measured on a Unicam SP-1200 spectrophotomeer using KBr wafer technique. ^{1}H NMR spectra were measured in DMSO-d_6 on a Varian plus instrument (300 MHz). Mass spectra were recorded on a Shimadzu GC-MS QP1000Ex instrument operating at 70 eV in EI mode.

*Furan-2(3*H*)-thione derivatives* **(2)**: To a solution of (0.01 mole) in freshly distilled dry toluene (50 mL), phosphorus pentasulfide (0.03 mOl) was added and the reaction mixture heated under reflux for 6 h, cooled, filtered, solvent removed from the filtrate under reduced pressure and the residue treated with petroleum ether (60–80) to give a solid. It was filtered, washed thoroughly with light petroleum and recrystallised from a suitable solvent.

3-[(furan-2-yl)methylene]-5-phenylfuran-2(3H)-thione (**2a**), *Ar = C_6H_5*: Reddish brown crystals (30% yield), m.p. 154–156 °C (pet./benzene). IR: ν_{max} 1246 (C=S), 1650, 1600 (C=C) cm^{-1}. EI-MS: *m/z* (%) 254 ($M^{+\cdot}$, 38), 187 (30), 177 (70), 133 (50), 110 (80), 77 (base). ^{1}H NMR (DMSO-d_6): δ 6.51 (s, 1H, Ha), 7.01–8.07 (m, 9H, ArH). Anal. Calcd for $C_{15}H_{10}O_2S$: C, 70.83; H, 3.96; S, 12.61. Found C, 71.38; H, 4.01; S, 12.37%.

3-[(furan-2-yl)methylene]-5-(4-chlorophenyl)furan-2(3H)-thione (**2a**), *Ar = C_6H_4Cl(p-)*: Reddish brown crystals (50% yield), m.p. 177–179 °C (pet./benzene). IR: ν_{max} 1250 (C=S), 1645, 1599 (C=C) cm^{-1}. EI-MS: *m/z* (%) 290 ($M^{+\cdot}$ + 2, 5.3), 289 (35), 288 ($M^{+\cdot}$, 15), 244 (30), 221 (45), 177 (60), 111 (30), 110 (90), 77 (base). ^{1}H NMR (DMSO-d_6): δ 6.58 (s, 1H, Ha), 6.90–7.95 (m, 8H, ArH). Anal. Calcd for $C_{15}H_9ClO_2S$: C, 62.37; H, 3.14; Cl, 12.28; S, 11.11. Found C, 61.84; H, 3.29; Cl, 12.73; S, 11.25%.

3-[(furan-2-yl)methylene]-5-(4-methoxyphenyl)furan-2(3H)-thione (**2a**), *Ar = $C_6H_4OCH_3$(p-)*: Reddish brown crystals (40% yield), m.p. 131–133 °C (pet./benzene). IR: ν_{max} 1252 (C=S), 1650, 1620 (C=C) cm^{-1}. EI-MS: *m/z* (%) 284 ($M^{+\cdot}$, 12), 269 (25), 177 (80), 110 (90), 77 (base). ^{1}H NMR (DMSO-d_6): δ 3.9 (s, 3H, –OCH_3) 6.50 (s, 1H, Ha), 7.1–7.9 (m, 8H, ArH). Anal. Calcd for $C_{16}H_{12}O_3S$: C, 67.57; H, 4.25; S, 11.28. Found C, 67.84; H, 4.10; S, 11.33%.

3-[(1, 3-diphenyl-1H-pyrazol-4-yl)methylene]-5-phenylfuran-2(3H)-thione (**2b**), *Ar = C_6H_5*-: Reddish brown crystals (35% yield), m.p. 135–137 °C (ethanol). IR: ν_{max} 1253 (C=S), 1640, 1599 (C=C) cm^{-1}. EI-MS: *m/z* (%) 407 ($M^{+\cdot}$ + 1, 21), 406 ($M^{+\cdot}$, 30), 257 (34), 121 (33), 105 (51), 91 (87), 77 (base), 65 (31), 64 (73), 51 (47), 50 (30). ^{1}H NMR (DMSO-d_6): δ 7.31 (s, 1H, Ha), 7.42–8.75 (m, 16H, ArH). Anal. Calcd for $C_{26}H_{18}N_2OS$: C, 76.80; H, 4.46; N, 6.89; S, 7.89. Found C, 77.14; H, 4.40; N, 6.47; S, 7.68%.

3-[(1, 3-diphenyl-1H-pyrazol-4-yl)methylene]-5-(4-chlorophenyl) furan-2(3H)-thione (**2b**), *Ar = C_6H_4Cl(p-)*: Reddish brown crystals (50% yield), m.p. 125–127 °C (ethanol). IR: ν_{max} 1247 (C=S), 1600, 1592 (C=C) cm^{-1}. ^{1}H NMR (DMSO-d_6): δ 7.28 (s, 1H, Ha), 7.61–8.95 (m, 16H, ArH). Anal. Calcd for $C_{26}H_{17}ClN_2OS$: C, 70.80; H, 3.89; Cl, 8.04; N, 6.35; S, 7.27. Found C, 71.24; H, 3.75; Cl, 7.89; N, 6.01; S, 7.45%.

3-[(1, 3-diphenyl-1H-pyrazol-4-yl)methylene]-5-(4-methoxyphenyl) furan-2(3H)-thione (**2b**), *Ar = $C_6H_4OCH_3$(p-)*: Reddish brown crystals (50% yield), m.p. 160–162 °C (ethanol). IR: ν_{max} 1251 (C=S), 1598, 1610 (C=C) cm^{-1}. ^{1}H NMR (DMSO-d_6): δ 3.78 (s, 3H, OCH_3), 7.15 (s, 1H, Ha), 7.23–8.23 (m, 16H, ArH). Anal. Calcd for $C_{27}H_{20}N_2O_2S$: C, 74.29; H, 4.62; N, 6.42; S, 7.35. Found C, 74.70; H, 4.58; N, 6.28; S, 7.62%.

3-[(1H-indol-3-yl)methylene]-5-phenylfuran-2(3H)-thione (**2c**), *Ar = C_6H_5*-: Reddish brown crystals (40% yield), m.p. 157–159 °C (ethanol). IR: ν_{max} 1250 (C=S), 1620, 1600 (C=C) cm^{-1}. EI-MS: *m/z* (%) 304 (5), 303 ($M^{+\cdot}$, 26), 121 (30), 105 (40), 91 (70), 77 (base), 51 (48). ^{1}H NMR (DMSO-d_6): δ 6.87 (s, 1H, Ha), 7.14–8.23 (m, 12H, NH + ArH). Anal. Calcd for $C_{19}H_{13}NOS$: C, 75.20; H, 4.32; N, 4.62; S, 10.57. Found C, 75.39; H, 4.38; N, 4.69; S, 10.93%.

3-[(1H-indol-3-yl)methylene]-5-(4-chlorophenyl)furan-2(3H)-thione (**2c**), *Ar = C_6H_4Cl(p-)*: Reddish brown crystals (30% yield), m.p.

142–144 °C (ethanol). IR: ν_{max} 1256 (C=S), 1589, 1605 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 6.83 (s, 1H, Ha), 7.21–8.17 (m, 11H, NH + ArH). Anal. Calcd for $C_{19}H_{12}ClNOS$: C, 67.53; H, 3.58; Cl, 10.50; N, 4.15; S, 9.49. Found C, 66.98; H, 3.49; Cl, 10.20; N, 4.32; S, 9.17%.

3-[(1H-indol-3-yl)methylene]-5-(4-methoxyphenyl)furan-2(3H)-thione (**2c**)*, Ar = $C_6H_4OCH_3(p$-)*: Reddish brown crystals (60% yield), m.p. 165–166 °C (ethanol). IR: ν_{max} 1252 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 3.9 (s, 3H, OCH_3), 6.87 (s, 1H, Ha), 7.15–8.29 (m, 11H, NH + ArH). Anal. Calcd for $C_{20}H_{15}NO_2S$: C, 72.03; H, 4.53; N, 4.20; S, 9.62. Found C, 71.90; H, 4.87; N, 4.10; S, 9.23%.

3-Heteryl(aryl)methyl-5-arylfuran-2(3H)thione (**4–6**): *general procedure*

To a stirred mixture of anhydrous $AlCl_3$ (0.03 mole) in dry benzene, toluene or anisole (100 mL), a solution of the furan-2(3*H*)-thione (**2**) (0.01 mole) in benzene, toluene or anisole was added dropwise at 10–20 °C. After complete addition, the reaction mixture was stirred at room temperature for an additional 15 h. The complex formed was decomposed with 15% aqueous HCl and hence steam-distilled to remove the excess of organic solvent. The solid formed was filtered off and extracted by $CHCl_3$. The solid product obtained was recrystallised from the solvent specified.

3-[(Furan-2-yl)phenylmethyl]-5-phenylfuran-2(3H)-thione **(4a)**, *Ar = Ar′ = C_6H_5-*: Brown crystals (20% yield), m.p. 320–322 °C (ethanol). IR: ν_{max} 1250 (C=S), 1600, 1610 (C=C) cm^{-1}. EI-MS: *m/z* (%) 333 (8), 332 ($M^{+\cdot}$, 33), 287 (40), 171 (50), 170 (30), 259 (60), 258 (base), 77 (70). ^1H NMR (DMSO-d_6): δ 3.1 (t, 1H, CH), 3.9 (d, 1H, CH), 7.10–8.19 (m, 14H, ArH). Anal. Calcd for $C_{21}H_{16}O_2S$: Calcd. C, 75.88; H, 4.85; S, 9.65. Found C, 76.97; H, 4.75; S, 9.29%.

3-[(Furan-2-yl)(4-methylphenyl)methyl]-5-phenylfuran-2(3H)-thione **(4b)**, *Ar = C_6H_5-, Ar′ = $C_6H_4CH_3(p$-)*: Brown crystals (30% yield), m.p. 298–300 °C (ethanol). IR: ν_{max} 1252 (C=S), 1595, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.9 (t, 1H, CH), 4.1 (d, 1H, CH), 2.31 (s, 3H, CH_3), 6.59–8.13 (m, 13H, ArH). Anal. Calcd for $C_{22}H_{18}O_2S$: Calcd. C, 76.27; H, 5.24; S, 9.26. Found C, 76.62; H, 4.87; S, 9.12%.

3-[(Furan-2-yl)(4-methoxyphenyl)methyl]-5-phenylfuran-2(3H)-thione **(4c)**, *Ar = C_6H_5-, Ar′ = $C_6H_4OCH_3(p$-)*: Brown crystals (40% yield), m.p. 305–307 °C (ethanol). IR: ν_{max} 1255 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 3.2 (t, 1H, CH), 3.90 (s, 3H, OCH_3), 4.1 (d, 1H, CH), 6.59–8.07 (m, 13H, ArH). Anal. Calcd for $C_{22}H_{18}O_3S$: Calcd. C, 72.90; H, 5.01; S, 8.85. Found C, 73.09; H, 5.25; S, 8.77%.

5-(4-Chlorophenyl)-3-[(furan-2-yl)phenylmethyl]furan-2(3H)-thione **(4d)**, *Ar = $C_6H_4Cl(p$-), Ar′ = C_6H_5-*: Brown crystals (25% yield), m.p. 340–342 °C (ethanol). IR: ν_{max} 1245 (C=S), 1600, 1615 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 6.69–8.01 (m, 13H, ArH). Anal. Calcd for $C_{21}H_{15}ClO_2S$: Calcd. C, 68.75; H, 4.12; S, 8.74; Cl, 9.66. Found C, 69.52; H, 3.96; S, 8.45; Cl, 9.89%.

5-(4-Chlorophenyl)-3-[(furan-2-yl)(4-methylphenyl)methyl]furan-2(3H)-thione **(4e)**, *Ar = $C_6H_4Cl(p$-), Ar′ = $C_6H_4CH_3(p$-)*: Brown crystals (30% yield), m.p. 308–310 °C (ethanol). IR: ν_{max} 1255 (C=S), 1590, 1609 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.35 (s, 3H, CH_3), 3.1 (t, 1H, CH), 3.9 (d, 1H, CH), 6.65–7.97 (m, 12H, ArH). Anal. Calcd for $C_{22}H_{17}ClO_2S$: Calcd. C, 69.37; H, 4.50; Cl, 9.31; S, 8.42. Found C, 69.68; H, 4.20; Cl, 9.71; S, 8.70%.

5-(4-Chlorophenyl)-3-[(furan-2-yl)(4-methoxyphenyl)methyl]furan-2(3H)-thione **(4f)**, *Ar = $C_6H_4Cl(p$-), Ar′ = $C_6H_4OCH_3(p$-)*: Brown crystals (20% yield), m.p. 310–312 °C (ethanol). IR: ν_{max} 1260 (C=S), 1590, 1610 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.9 (t, 1H, CH), 3.98 (s, 3H, OCH_3), 4.1 (d, 1H, CH), 6.78–8.05 (m, 12H, ArH). Anal. Calcd for $C_{22}H_{17}ClO_3S$: C, 66.58; H, 4.32 Cl, 8.93; S, 8.08. Found C, 66.93; H, 4.61; Cl, 9.22; S, 8.17%.

3-[(Furan-2-yl)phenylmethyl]-5-(4-methoxyphenyl)furan-2(3H)-thione **(4g)**, *Ar = $C_6H_4OCH_3(p$-), Ar′ = C_6H_5-*: Brown crystals (20% yield), m.p. 296–298 °C (ethanol). IR: ν_{max} 1248 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.90(t, 1H, CH), 3.80 (s, 3H, OCH_3), 4.09(d, 1H, CH), 6.90–7.89 (m, 13H, ArH). Anal. Calcd for $C_{22}H_{18}O_3S$: C, 72.90; H, 5.01; S, 8.85. Found C, 73.32; H, 4.58; S, 9.27%.

3-[(Furan-2-yl)(4-methylphenyl)methyl]-5-(4-methoxyphenyl)-furan-2(3H)-thione **(4h)**, *Ar = $C_6H_4OCH_3(p$-), Ar′ = $C_6H_4CH_3(p$-)*: Brown crystals (25% yield), m.p. 330–333 °C (ethanol). IR: ν_{max} 1250 (C=S), 1590, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.34 (s, 3H, CH_3), 3.1 (t, 1H, CH), 3.93 (s, 3H, OCH_3), 4.21 (d, 1H, CH), 6.94–8.03 (m, 12H, ArH). Anal. Calcd for $C_{23}H_{20}O_3S$: C, 73.38; H, 5.35; S, 8.52. Found C, 73.03; H, 4.97; S, 8.63%.

3-[(Furan-2-yl)(4-methoxyphenyl)methyl]-5-(4-methoxyphenyl) furan-2(3H)-thione **(4i)**, *Ar = Ar′ = $C_6H_4OCH_3(p$-)*: Brown crystals (20% yield), m.p. 315–317 °C (ethanol). IR: ν_{max} 1256 (C=S), 1600, 1610 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 3.10 (t, 1H, CH), 3.76 (s, 3H, OCH_3), 3.83 (s, 3H, OCH_3), 4.12 (d, 1H, CH), 6.54–7.78 (m, 12H, ArH). Anal. Calcd for $C_{23}H_{20}O_4S$: C, 70.39; H, 5.14; S, 8.17. Found C, 70.90; H, 4.79; S, 8.33%.

3-[(1, 3-diphenyl-1H-pyrazol-4-yl)phenylmethyl]-5-phenylfuran-2(3H)-thione **(5a)**, *Ar = Ar′ = C_6H_5-*: Brown crystals (20% yield), m.p. 350–352 °C (ethanol). IR: ν_{max} 1254 (C=S), 1600, 1650 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.98 (t, 1H, CH), 3.92 (d, 1H, CH), 6.95–8.13 (m, 22H, ArH). Anal. Calcd for $C_{32}H_{24}N_2OS$: C, 79.31; H, 4.99; N, 5.78; S, 6.62. Found C, 79.76; H, 4.70; N, 5.93; S, 6.80%.

3-[(1, 3-diphenyl-1H-pyrazol-4-yl)(4-methylphenyl)methyl]-5-phenylfuran-2(3H)-thione **(5b)**, *Ar = C_6H_5-, Ar′ = $C_6H_4CH_3(p$-)*: Brown crystals (30% yield), m.p. 335–337 °C (benzene/ethanol). IR: ν_{max} 1245 (C=S), 1600, 1646 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.34 (s, 3H, CH_3), 3.12(t, 1H, CH), 4.21(d, 1H, CH), 6.90–8.09 (m, 21H, ArH). Anal. Calcd for $C_{33}H_{26}N_2OS$: C, 79.49; H, 5.26; N, 5.62; S, 6.43. Found C, 79.68; H, 4.93; N, 5.35; S, 6.72%.

3-[(1, 3-diphenyl-1H-pyrazol-4-yl)(4-methoxyphenyl)methyl]-5-phenylfuran-2(3H)-thione **(5c)**, *Ar = C_6H_5-, Ar′ = $C_6H_4OCH_3(p$-)*: Brown crystals (30% yield), m.p. 335–337 °C (benzene/ethanol). IR: ν_{max} 1256 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 3.10 (t, 1H, CH), 3.91 (s, 3H, OCH_3), 4.10 (d, 1H, CH), 6.95–8.03 (m, 21H, ArH). Anal. Calcd for $C_{33}H_{26}N_2O_2S$: C, 77.02; H, 5.09; N, 5.44; S, 6.23. Found C, 77.59; H, 4.89; N, 5.62; S, 6.52%.

3-[(1, 3-diphenyl-1H-pryazol-4-yl)phenylmethyl]-5-(4-chlorophenyl)furan-2(3H)-thione **(5d)**, *Ar = C_6H_4Cl-, Ar′ = C_6H_4–*: Brown crystals (30% yield), m.p. 330–332 °C (ethanol). IR: ν_{max} 1252 (C=S), 1600, 1615 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.95 (t, 1H, CH), 3.98 (d, 1H, CH), 6.95–7.89 (m, 21H, ArH). EI-MS *m/z* (%) 520 (15), 518 (50), 424 (30), 257 (80), 139 (55), 111 (40), 77 (base), 51 (45). Anal. Calcd for $C_{32}H_{23}ClN_2OS$: C, 74.05; H, 4.47; N, 5.40; Cl, 6.83; S, 6.18. Found C, 74.49; H, 4.17; N, 5.67; Cl, 7.02; S, 6.09%.

3-[(1, 3-diphenyl-1H-pyrazol-4-yl)(4-methylphenyl)methyl]-5-(4-chlorophenyl)furan-2(3H)-thione **(5e)**, *Ar = C_6H_4Cl-, Ar′ = $C_6H_4CH_3$–*: Brown crystals (35% yield), m.p. 250–252 °C (benzene/ethanol). IR: ν_{max} 1250 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.34 (s, 3H, CH_3), 3.01 (t, 1H, CH), 3.94 (d, 1H, CH), 6.95–7.89 (m, 20H, ArH). Anal. Calcd for $C_{33}H_{25}ClN_2OS$: C, 74.35; H, 4.73; Cl, 6.65; N, 5.25; S, 6.02. Found C, 74.82; H, 4.50; Cl, 6.86; N, 5.34; S, 6.23%.

3-[(1, 3-diphenyl-1H-pyrazol-4-yl)(4-methoxyphenyl)methyl]-5-(4-chlorophenyl) furan-2(3H)-thione **(5f)**, *Ar = C_6H_4Cl-, Ar′ = $C_6H_4OCH_3$–*: Brown crystals (30% yield), m.p. > 360 °C (ethanol). IR: ν_{max} 1250 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 3.12 (t, 1H, CH), 4.09 (d, 1H, CH), 3.84 (s, 3H, OCH_3), 6.92–7.83 (m, 20H, ArH). Anal. Calcd for $C_{33}H_{25}ClN_2O_2S$: C, 72.18; H, 4.59; Cl, 6.46; N, 5.10; S, 5.84. Found C, 72.70; H, 4.34; Cl, 6.23; N, 5.29; S, 5.71%.

3-[(1, 3-diphenyl-1H-pyrazol-4-yl)phenylmethyl]-5-(4-methoxy-phenyl) furan-2(3H)-thione **(5g)**, *Ar = $C_6H_4OCH_3(p$-), Ar′ = C_6H_4–*: Brown crystals (45% yield), m.p. 348–350 °C (benzene/ethanol). IR: ν_{max} 1252 (C=S), 1600, 1625 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.98 (t, 1H, CH), 3.75 (s, 3H, OCH_3), 3.98 (d, 1H, CH), 7.08–7.93 (m, 21H, ArH). Anal. Calcd for $C_{33}H_{26}N_2O_2S$: C, 77.02; H, 5.09; N, 5.44; S, 6.23. Found C, 77.49; H, 4.87; N, 5.53; S, 6.40%.

3-[(1, 3-diphenyl-1H-pyrazol-4-yl)(4-methylphenyl)methyl]-5-(4-methoxyphenyl)furan-2(3H)-thione **(5h)**, *Ar = $C_6H_4OCH_3(p$-), Ar′ =$C_6H_4CH_3(p$-)*: Brown crystals (40% yield), m.p. 350–352 °C (benzene/ethanol). IR: ν_{max} 1252 (C=S), 1600, 1610 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.30 (s, 3H, CH_3), 2.87 (t, 1H, Ha), 3.93 (s, 3H, OCH_3), 4.23 (d, 1H, CH), 7.19–8.12 (m, 20H, ArH). Anal. Calcd for $C_{34}H_{28}N_2O_2S$: C, 77.24; H, 5.34; N, 5.30; S, 6.07. Found C, 77.69; H, 4.73; N, 5.60; S, 6.20%.

3-[(1, 3-diphenyl-1H-pryazol-4-yl)(4-methoxyphenyl)methyl]-5-(4-methoxyphenyl)furan-2(3H)-thione **(5i)**, *Ar = Ar′ = $C_6H_4OCH_3(p$-)*: Brown crystals (45% yield), m.p. 320–323 °C (benzene/ethanol). IR: ν_{max} 1260 (C=S), 1600, 1620 (C=C)cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.92 (t, 1H, CH), 3.81 (s, 3H, OCH_3), 3.93 (s, 3H, OCH_3), 4.13 (d, 1H, CH), 6.95–8.07 (m, 20H, ArH). Anal. Calcd for $C_{34}H_{28}N_2O_3S$: C, 74.98; H, 5.18; N, 5.14; S, 5.89. Found C, 75.37; H, 4.95; N, 5.30; S, 5.68%.

3-[(1H-indole-3-yl)phenylmethyl]-5-phenylfuran-2(3H)-thione **(6a)**, *Ar = Ar′ = C_6H_5-*: Brown crystals (20% yield), m.p. 336–338 °C (ethanol). IR: ν_{max} 1250 (C=S), 1598, 1615 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 3.03 (t, 1H, CH), 4.10 (d, 1H, CH), 6.90–8.19 (m, 17H, NH + 16ArH). Anal. Calcd for $C_{25}H_{19}NOS$: C, 78.71; H, 5.02; N, 3.67; S, 8.41. Found C, 78.24; H, 4.68; N, 3.54; S, 8.73%.

3-[(1H-indole-3-yl)(4-methylphenyl)methyl]-5-phenylfuran-2(3H)-thione **(6b)**, *Ar* = C_6H_5-, *Ar′* = $C_6H_4CH_3$(*p-*): Brown crystals (25% yield), m.p. 349–351 °C (ethanol). IR: ν_{max} 1245 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.35 (s, 3H, CH_3), 2.97 (t, 1H, CH), 3.99 (d, 1H, CH), 6.91–8.10 (m, 16H, NH + 15ArH). Anal. Calcd for $C_{26}H_{21}NOS$: C, 78.95; H, 5.35; N, 3.54; S, 8.11. Found C, 79.52; H, 4.93; N, 3.74; S, 8.40%.

3-[(1H-indole-3-yl)(4-methoxyphenyl)methyl]-5-phenylfuran-2(3H)-thione **(6c)**, *Ar* = C_6H_5-, *Ar′* = $C_6H_4OCH_3$(*p-*): Brown crystals (30% yield), m.p. 335–337 °C (benzene/ethanol). IR: ν_{max} 1250 (C=S), 1600, 1615 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 3.07 (t, 1H, CH), 3.92 (s, 3H, OCH_3), 4.02 (d, 1H, CH), 6.98–8.09 (m, 16H, NH + 15ArH). Anal. Calcd for $C_{26}H_{21}NO_2S$: C, 75.88; H, 5.14; N, 3.42; S, 7.79. Found C, 76.35; H, 4.83; N, 3.57; S, 7.53%.

3-[(1H-indole-3-yl)phenylmethyl]-5-(4-chlorophenyl)furan-2(3H)-thione **(6d)**, *Ar* = C_6H_4Cl(*p-*), *Ar′* = C_6H_5-: Brown crystals (35% yield), m.p. 315–318 °C (benzene/ethanol). IR: ν_{max} 1252 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.91 (t, 1H, CH), 4.07 (d, 1H, CH), 6.92–7.95 (m, 16H, NH + 15ArH). Anal. Calcd for $C_{25}H_{18}ClNOS$: C, 72.19; H, 4.36; Cl, 8.52; N, 3.37; S, 7.71. Found C, 72.70; H, 3.97; Cl, 8.71; N, 3.50; S, 7.89%.

3-[(1H-indole-3-yl)(4-methylphenyl)methyl]-5-(4-chlorophenyl) furan-2(3H)-thione **(6e)**, *Ar* = C_6H_4Cl(*p-*), *Ar′* = $C_6H_4CH_3$(*p-*): Brown crystals (40% yield), m.p. 347–349 °C (ethanol). IR: ν_{max} 1250 (C=S), 1600, 1615 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.39 (s, 3H, CH_3), 2.95 (t, 1H, CH), 4.15 (d, 1H, CH), 6.97–8.13 (m, 15H, NH + 14ArH). Anal. Calcd for $C_{26}H_{20}ClNOS$: C, 72.61; H, 4.69; Cl, 8.25; N, 3.26; S, 7.46. Found C, 73.21; H, 4.42; Cl, 8.40; N, 3.39; S, 7.65%.

3-[(1H-indole-3-yl)(4-methoxyphenyl)methyl]-5-(4-chlorophenyl) furan-2(3H)-thione **(6f)**, *Ar* = C_6H_4Cl(*p-*), *Ar′* = $C_6H_4OCH_3$(*p-*): Brown crystals (40% yield), m.p. >360 °C (ethanol). IR: ν_{max} 1259 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 3.12 (t, 1H, CH), 3.83 (s, 3H, OCH_3), 4.13 (d, 1H, CH), 6.97–7.99 (m, 15H, NH + 14ArH). Anal. Calcd for $C_{26}H_{20}ClNO_2S$: C, 70.02; H, 4.52; Cl, 7.95; N, 3.14; S, 7.19. Found C, 70.52; H, 4.21; Cl, 8.13; N, 3.30; S, 7.36%.

3-[(1H-indole-3-yl)phenylmethyl]-5-(4-methoxyphenyl)furan-2(3H)-thione **(6g)**, *Ar* = $C_6H_4OCH_3$(*p-*), *Ar′* = C_6H_5-: Brown crystals (45% yield), m.p. 345–347 °C (ethanol). IR: ν_{max} 1245 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 2.91 (t, 1H, CH), 3.85 (s, 3H, OCH_3), 4.03 (d, 1H, CH), 7.01–8.09 (m, 16H, NH + 15ArH). Anal. Calcd for $C_{26}H_{21}NO_2S$: C, 75.88; H, 5.14; N, 3.40; S, 7.79. Found C, 75.38; H, 4.71; N, 3.50; S, 7.68%.

3-[(1H-indole-3-yl)(4-methylphenyl)methyl]-5-(4-methoxyphenyl) furan-2(3H)-thione **(6h)**, *Ar* = $C_6H_4OCH_3$(*p-*), *Ar′* = $C_6H_4CH_3$(*p-*): Brown crystals (35% yield), m.p. 299–301 °C (ethanol). IR: ν_{max} 1259 (C=S), 1590, 1610 (C=C) cm^{-1}. EI-MS *m/z* (%) 425 (35), 257 (60), 139 (50), 110 (30), 77 (base). ^1H NMR (DMSO-d_6): δ 2.29 (s, 3H, CH_3), 3.07(t, 1H, CH), 3.92 (s, 3H, OCH_3), 4.17(d, 1H, CH), 6.94–8.05 (m, 15H, NH + 14ArH). Anal. Calcd for $C_{27}H_{23}NO_2S$: C, 76.21; H, 5.45; N, 3.29; S, 7.54. Found C, 76.39; H, 5.13; N, 3.47; S, 7.39%.

3-[(1H-indole-3-yl)(4-methoxyphenyl)methyl]-5-(4-methoxyphenyl) furan-2(3H)-thione **(6i)**, *Ar* = *Ar′* = $C_6H_4OCH_3$(*p-*): Brown crystals (40% yield), m.p. 320–323 °C (ethanol). IR: ν_{max} 1250 (C=S), 1600, 1620 (C=C) cm^{-1}. ^1H NMR (DMSO-d_6): δ 3.12 (t, 1H, CH), 3.80 (s, 3H, OCH_3), 3.94 (s, 3H, OCH_3), 4.17 (d, 1H, CH), 6.97–7.98 (m, 15H, NH + 14ArH). Anal. Calcd for $C_{27}H_{23}NO_3S$: C, 73.44; H, 5.25; N, 3.17; S, 7.26. Found C, 73.90; H, 4.85; N, 3.31; S, 7.43%.

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