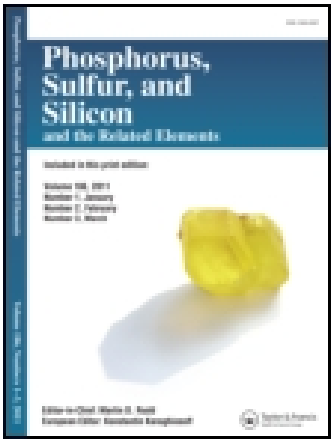

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Synthesis and Properties of Novel Imidazolone Derivatives Containing a Sulfur Atom

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Synthesis and Properties of Novel Imidazolone Derivatives Containing a Sulfur Atom

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*Novel 5-(2-chlorophenylmethylidene)-2-thio-4-imidazolinones **3** and 2-Alkythio-5-(2- chlorophenylmethylidene)-4H-imidazolin-4-ones **4** have been synthesized via a tandem aza-Wittig reaction to develop more imidazolinones that may possess biological activities. The target compounds were identified by GC-MS, IR, and ^1H NMR spectroscopies, and element analysis, and, in the case of **4k**, its structure was established by single crystal X-ray diffraction. They showed not only fungicidal activities against Gibberella zeae, Cercospora beticola, Fusarium oxysporium, Rhizoctonia solani, and Botryosphaeria berengeriana, but also growth inhibition of Barnyard grass and Cole root and stalk.*

Keywords aza-Wittig reaction; crystal structure; fungicidal activities; herbicidal activities; Imidazolinone derivatives; vinyliminophosphorane

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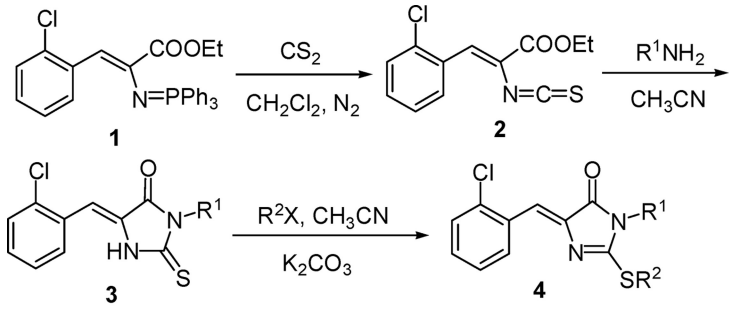
INTRODUCTION

Imidazolinone derivatives exhibit various biological properties. Some of them have been reported to posses a broad spectrum of pharmacological actions, which are reflected by their use as anticonvulsant.[1–3] antiviral,[4] antitumor,[5] antibacterial,[6] anti-inflammatory[7] and hypotensive agents.[8] Some have been found to possess fungicidal activities; for example, 5-methyl-2- methylthio-5-phenyl-3-phenylamine-3,5-dihydro-imidazolin-4-one (RPA407213) shows high fungicidal activity.[9] And the literature also reveals that a number of imidazolinones are selective herbicides,[10] which inhibit acetolactate synthase[11–12]or acetohydroxyacid synthase.[13] In view of these facts, we have synthesized a variety of imidazolinones via a tandem aza-Wittig reaction and evaluated their biological activities.[14–18] Now we report the synthesis and biological activities of some new 2-alkylthio-5-(2-chlorophenyl-methylidene)-4*H*-imidazolin-4-ones.

RESULTS AND DISCUSSION

The synthetic pathway for the title compounds **4** is shown in Scheme 1. The intermediate vinyliminophosphorane **1** was prepared according the literature method.[19] 3-(2-Chlorophenyl)-2-isothiocyanato acrylic acid ethyl ester **2** can be synthesized from vinyliminophosphorane **1** with carbon disulfide via a tandem aza-Wittig reaction. Intramolecular cyclocondensation of the intermediate **2** in situ with R^1NH_2



1 **2** **3** **4**

X = Cl, Br, I

3a: R^1 = *n*-Pr **3b**: R^1 = *i*-Pr **3c**: R^1 = *n*-Bu **3d**: R^1 = *i*-Bu **3e**: R^1 = *t*-Bu

4a: R^1 = *n*-Pr, R^2 = Me **4b**: R^1 = *n*-Pr, R^2 = Allyl **4c**: R^1 = *n*-Pr, R^2 = CH_2COOEt

4d: R^1 = *n*-Pr, R^2 = Benzyl **4e**: R^1 = *i*-Pr, R^2 = CH_2COOEt **4f**: R^1 = *i*-Pr, R^2 = Benzyl

4g: R^1 = *n*-Bu, R^2 = CH_2COOEt **4h**: R^1 = *n*-Bu, R^2 = Benzyl **4i**: R^1 = *n*-Bu, R^2 = Propargyl

4j: R^1 = *i*-Bu, R^2 = CH_2COOEt **4k**: R^1 = *i*-Bu, R^2 = Benzyl **4l**: R^1 = *t*-Bu, R^2 = Me

SCHEME 1

at r.t. gave the previously unreported 5-(2-chlorophenylmethylidene)-2-thio-4-imidazolinones **3**, which reacted with R^2X (X = Cl, Br, I) in the presence of K_2CO_3 (s) to give **4** in 56–79%. When R^1X is CH_3I, the S-alkylation reaction could be carried out at r.t. When R^1X is $BrCH_2COOEt$ or $PhCH_2Cl$, the S-alkylation reaction required heating. Twelve novel 5-(2-chlorophenylmethyllidene)-4*H*-imidazolin-4-ones were synthesized and identified by GC-MS, IR, elemental analysis, and ^1H NMR spectroscopies.

A single crystal of **4k** was grown from CH_2Cl_2, and ether (1:1, v/v) was confirmed by X-ray diffraction analysis as shown in Figure 1. Diffraction measurements were carried out on a Bruker APEX area-detector diffractometer (graphite-monochromatized Mo-Kα radiation, λ = 0.71073 Å). The hydrogen atoms were added according to the theoretical models. The structure was refined by full-matrix least-squares method on F^2 with anisotropic thermal parameters for all non-hydrogen atoms. The programs for structure solution and refinement are SHELXS-97[20] and SHELXL-97,[21] respectively. Crystal data are summarized in Table I. The crystallographic data was deposited at CCDC.[22] Compounds **4** may exist in (Z)- or (E)-isomeric forms with respect to the exocyclic C=C double bond. We had reported that the configuration of 2-alkylamino-3-aryl-5-phenylmethylene-3,5-dihydro-4*H*-imidazo-4-lones could be

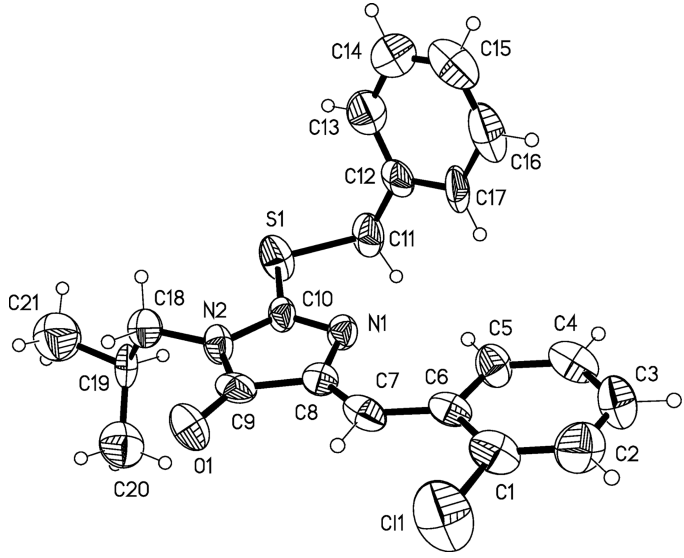


FIGURE 1 The molecular structure of **4k**, with the atom-numbering scheme. Displacement ellipsoids are drawn at the 50% probability level.

TABLE I Crystal Data and Summary of Data Collection and Structure Refinement of 4k

Formal	$C_{21}H_{21}ClN_2OS$
Temperature (K)	298(2)
Wavelength (Å)	0.71073
Crystal system	Monoclinic
Space group	P 21/c
a (Å)	5.8814(5)
b (Å)	20.843(2)
c (Å)	16.6068(15)
$\alpha(^\circ)$	90
$\beta(^\circ)$	104.594(4)
$\gamma(^\circ)$	90
Volume ($Å^3$)	1970.1(3)
Z	4
Calculated density (Mg mm^{-3})	1.298
Absorption coefficient (mm^{-1})	0.312
F(000)	808
Crystal size (mm)	$0.32 \times 0.16 \times 0.13$
θ Range for data collection (^{o})	1.60–25.02
Limiting indices	$-5 \le h \le 6, -24 \le k \le 24, -19 \le l \le 19$
Reflections collection/unique	10288/3461 [R(int) = 0.0559]
Completeness to $\theta = 25.19^\circ$	100.0%
Absorption correction	Semi-empirical from equivalents
Refinement method	Full-matrix least-squares on F^2
Goodness-of fit on F^2	1.465
Final R indices [I $>2\sigma$ (I)]	$R_1 = 0.1056$, $wR_2 = 0.2258$
Largest diffusion peak and hole (e A^{-3})	1.030 and −1.275

determined as in (Z)-form by analyzing its ^{13}C NMR spectrum.[23] Now the X-ray crystal structure of **4k** indicates the compounds exist as (Z)-form.

The biological activities of all compounds **4a–l** were investigated. The method of testing adopted was taken from the literature.[18] The results are summarized in Tables II and Table III. The results of Table II show that some compounds exhibited good fungicidal activities. For example, in 50 μg/mL, **4i** exhibited 86.6% inhibition of *Gibberella zeae* and 90.0% inhibition of *Cercospora beticol*, while **4e** showed 93.3% inhibition of *Rhizoctonia solani*. The best one was compound **4c**, which exhibited more than 86% inhibition of *G. zeae*, *C. beticola*, and *Fusarium oxysporium*, respectively.

The studies of the biological activities of 5-arylmethylimidazolinone derivatives were focused on fungicidal activities in the literatures.[24–26] In our previous research, we found 2,3,5-trisubstituted imidazolinones

TABLE II The Fungicidal Activity of Compounds 4a–4l (50 μg/mL, Inhibition %)

Entry	Gibberella zeae	Cercospora beticola	Fusarium oxysporium	Rhizoctonia solani	Botryosphaeria berengeriana
4a	86.6	75.0	19.2	76.6	66.7
4b	13.0	16.7	8.6	6.7	77.5
4c	86.6	90.0	92.3	50.0	46.7
4d	46.7	75.0	19.2	76.6	66.7
4e	46.7	75.0	53.8	93.3	20.0
4f	66.7	25.0	42.3	53.3	26.7
4g	0	60.0	41.2	6.3	25.0
4h	66.7	90.0	42.3	60.0	46.7
4i	86.6	90.0	65.4	66.7	33.3
4j	86.6	50.0	53.8	36.7	20.0
4k	26.7	75.0	80.7	73.3	46.7
4l	66.7	80.0	23.1	53.3	0

with heterocyclic substituent group at 5-position showed herbicidal activities to some extent.[18] The results of Table III show that compounds **4** with 2-chlorophenyl group at 5-position also exhibited herbicidal activities. For example, in 100 μg/mL, **4b**, **4d**, and **4k** showed 80.0%, 86.5%, and 91.9% inhibition of Barnyard grass (*Echinochloa crusgalli*) root, respectively, and **4b** also exhibited 83.6% inhibition of Cole (*Brassica campestris*) root.

TABLE III Herbicidal Activity of Compounds 4a–4l (Inhibition %)

	Cole		Barnyard grass	
Entry	100 μg/mL (Root/Stalk)	10 μg/mL (Root/Stalk)	100 μg/mL (Root/Stalk)	10 μg/mL (Root/Stalk)
4a	52.2/38.6	45.1/31.6	45.9/32.4	43.2/27.0
4b	83.6/44.4	51.7/8.9	80.0/4.5	62.5/0
4c	37.2/12.3	31.8/12.3	51.4/37.8	48.6/35.1
4d	65.5/35.1	53.9/21.1	86.5/37.8	45.9/27.0
4e	40.0/14.3	7.8/14.3	2.0/40.0	32.6/50.0
4f	25.5/30.9	23.3/16.7	16.3/33.3	18.4/36.7
4g	45.8/29.4	28.1/27.9	54.0/50.0	50.0/39.6
4h	60.2/22.8	45.1/22.8	67.6/29.7	59.5/24.3
4i	19.2/72.2	18.2/38.9	40.0/41.7	32.0/30.5
4j	46.7/28.6	34.4/14.3	18.4/40.0	38.8/36.7
4k	76.1/31.6	34.5/24.6	91.9/45.9	27.0/27.0
4l	56.6/21.1	38.9/15.8	54.1/43.2	37.8/37.8

In summary, novel 2-Alkythio-5-(2-chlorophenylmethylidene)-4*H*-imidazolin-4-ones **4** have been synthesized via a tandem aza-Wittig reaction and were identified by GC-MS, IR, and ^{1}H NMR spectroscopies, and element analysis. X-ray structure analysis of **4k** showed that the configuration of the target compounds is in (Z)-form. The results of bioassay indicated that some of the target compounds possessed signification fungicidal activities. Especially A few of them exhibited good herbicidal activities. It is worthwhile to optimize the structures.

EXPERIMENTAL

The ^{1}H NMR spectrum ($CDCl_3$) was recorded on a Varian XL-300 spectrometer with TMS as an internal standard, and IR spectrum was recorded on a Pekin-Elmer-1600 FT infrared spectrometer in KBr Pellets (ν in cm^{-1}). Mass spectra were recorded on a Finnigen TRACE GC-MS spectrometer. Elemental analyses were taken on a PE-2400-CHN elemental analysis instrument. Melting points were determined on an X_4 microscopic melting apparatus (uncorrected).

General Preparation of 5-(2-Chlorophenylmethylidene)-2-thio-4-imidazolinones 3

To a solution of vinyliminophosphorane **1** (2.43 g, 5 mmol) in dry dichloromethane was added carbon disulfide (3.80 g, 50 mmol), and the mixture was refluxed for 29 h under nitrogen. The solvent was removed under reduced pressure, and 20 mL ether and petroleum ether (1:2, v/v) was added to precipitate triphenylphosphine oxide. The solution was filtered, and the filtrate was condensed in vacuo keeping the temperature less 40°C to give 3-(2-chlorophenyl)-2- isothiocyanato acrylic acid ethyl ester **2**, which was used without purification. To a solution of **2** in 20 mL dry CH_3CN was added R^1NH_2 (if R^1 = *n*-Pr, 0.30 g, 5 mmol). The mixture was allowed to stand 3 h, and then a yellow solid precipitated from it. The solution was filtered, and the residue was recrystallized from dichloromethane/petroleum ether to give intermediate **3**.

3-Propyl-5-(2-chlorophenylmethylidene)-2-thio-4-imidazolidinone (3a)

Appearance: yellow crystal; yield 52%; m.p. 129–130°C; IR (KBr)ν/cm^{-1}: 3217 (NH), 1743 (C=O), 1671 (C=C), 1613, 1487, 1435 (Ar), 1226 (C=S); ^{1}H NMR (300 MHz, $CDCl_3$, pm): δ = 8.46 (brs, 1H, NH), 7.46–7.32 (m, 4H, Ar), 6.93 (s, 1H, =CH), 3.87 (t, 2H, J = 7.6 Hz, 2H, NCH_2), 1.80–1.72 (m, 2H, NCH_2CH_2), 0.98 (t, 3H, J = 7.2 Hz, CH_3). MS (EI, m/z, %): 280 (M^+, 55), 245 (74), 203 (100), 151 (56), 115 (53);

calcd. for $C_{13}H_{13}ClN_2OS$ (%): C, 55.61; H, 4.67; N, 9.98; found (%): C, 55.69; H, 4.71; N, 9.90.

3-i-Propyl-5-(2-chlorophenylmethylidene)-2-thio-4-imidazolidinone (3b)

Appearance: brown crystal; yield 55%; m.p. 113–115°C; IR (KBr)ν/cm^{-1}: 3217 (NH), 1704 (C=O), 1643 (C=C), 1585, 1487, 1452 (Ar), 1228 (C=S); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.48$ (brs, 1H, NH), 7.45–7.32 (m, 4H, Ar), 6.87(s, 1H, =CH), 4.96–4.90 (m, 1H, NCH), 1.55 (d, $J = 7.5$ Hz, 6H, $2CH_3$); MS (EI, m/z, %): 280 (M^+, 42), 245 (51), 203 (100), 151 (40), 115 (34); calcd. for $C_{13}H_{13}ClN_2OS$ (%): C, 55.61; H, 4.67; N, 9.98; found (%): C, 55.77; H, 4.19; N, 9.78.

3-Butyl-5-(2-chlorophenylmethylidene)-2-thio-4-imidazolidinone (3c)

Appearance: yellow crystal; yield 66%; m.p. 129–130°C; IR (KBr) ν/cm^{-1}: 3234 (NH), 1744 (C=O), 1670 (C=C), 1612, 1488, 1436 (Ar), 1223 (C=S); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.84$ (brs, 1H, NH), 7.55–7.32 (m, 4H, Ar), 6.93 (s, 1H, =CH), 3.90 (t, 2H, $J = 7.8$ Hz, NCH_2), 1.75–1.66 (m, 2H, NCH_2CH_2), 1.45–1.34 (m, 2H, $NCH_2CH_2CH_2$), 0.97 (t, 3H, $J = 7.4$ Hz, CH_3); MS (EI, m/z, %): 294 (M^+, 70), 259 (93), 203 (100), 151 (68), 115 (68); calcd. for $C_{14}H_{15}ClN_2OS$ (%): C, 57. 04; H, 5.13; N, 9.50; found (%): C, 57.22; H, 5.19; N, 9.55.

3-i-Butyl-5-(2-chlorophenylmethylidene)-2-thio-4-imidazolidinone (3d)

Appearance: Yellow crystal; Yield 54%; m.p. 133–135°C; IR (KBr)ν/cm^{-1}: 3217 (NH), 1739 (C=O), 1668 (C=C), 1604, 1491, 1437 (Ar), 1223 (C=S); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.47$ (brs, 1H, NH), 7.55–7.32 (m, 4H, Ar), 6.93 (s, 1H, =CH), 3.73 (d, 2H, $J = 7.2$Hz, NCH_2), 1.59–1.54 (m, 1H, NCH_2**CH**), 0.97 (d, 6H, $J = 6.6$ Hz, $2CH_3$); MS (EI, m/z, %) : 294 (M^+, 8), 259 (38), 203 (100), 151 (16), 115 (15); calcd. for $C_{14}H_{15}ClN_2OS$ (%): C, 57.04; H, 5.13; N, 9.50; Found (%): C, 57.34; H, 5.03; N, 9.28.

3-t-Butyl-5-(2-chlorophenylmethylidene)-2-thio-4-imidazolidinone (3e)

Appearance: yellow crystal; yield 50%; m.p. 144–146°C; IR (KBr)ν/cm^{-1}: 3233 (NH), 1724 (C=O), 1650 (C=C), 1585, 1483, 1444 (Ar), 1268 (C=S); ^{1}H NMR (300 M Hz, $CDCl_3$, ppm): $\delta = 8.52$ (brs, 1H, NH), 7.46–7.34 (m, 4H, Ar), 6.89 (s, 1H, =CH), 1.85 (s, 9H, $3CH_3$); MS (EI, m/z, %): 294 (M^+, 70), 259 (67), 203 (100), 151 (56), 115 (58); calcd.

for $C_{14}H_{15}ClN_2OS$ (%): C, 57.04; H, 5.13; N, 9.50; found (%): C, 56.99; H, 5.20; N, 9.63.

General Preparation of 2-Alkythio-5-(2-chlorophenylmethylidene)-4H-imidazolin-4-ones 4

A mixture of **3** (if R^1 = *n*-Pr, 0.22 g, 0.77 mmol) in 40 mL dry acetonitrile, alkyl halide (if $R^2X = CH_3I$, 0.22 g, 1.54 mmol), and solid K_2CO_3(0.18 g, 1.3 mmol) was stirred for 3 h at r.t. or 50–70°C and then filtered. The filtrate was concentrated under reduced pressure, and the residue was recrystallized from a mixture of dichloromethane, ether, and petroleum ether to give 2-Alkythio-5-(2-chlorophenylmethylidene)-4*H*-imidazolin-4-ones **4**.

2-Methylthio-3-propyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4a)

Appearance: light yellow crystal; yield, 69%; m.p.: 101–103°C; IR (KBr)ν/cm^{-1}: 1711 (C=O), 1633 (C=C), 1579 (C=N), 1558, 1490, 1438 (Ar).^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.85$ (d, 1H, $J = 8.7$ Hz, =CH), 7.41–7.24 (m, 4H, Ar), 3.57 (t, 2H, $J = 7.4$ Hz, NCH_2), 2.73 (s, 3H, SCH_3), 1.75–1.67 (m, 2H, NCH_2CH_2), 0.96 (t, 3H, $J = 7.4$ Hz, CH_2CH_3); MS (EI, m/z, %): 294 (M^+, 87), 259 (99), 217 (100), 150 (37); calcd. for $C_{14}H_{15}ClN_2OS$ (%): C, 57.04; H, 5.13; N, 9.50; found (%): C, 57.50; H, 5.02; N, 9.44.

2-Allylthio-3-propyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4b)

Appearance: orange crystal; yield 76%; m.p. 113–114°C; IR (KBr)ν/cm^{-1}: 1705 (C=O), 1630 (C=C), 1582 (C=N), 1486, 1466, 1434 (Ar);^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.83$ (d, 1H, $J = 9.0$ Hz, =CH), 7.39–7.21 (m, 4H, Ar), 6.06– 5.96 (m, 1H, SCH_2CH=), 5.42–5.22 (dd, 2H, $J_{cis} = 9.9$ Hz, $J_{trans} = 17.1$ Hz, =CH_2), 3.98 (d, 2H, $J = 6.6$ Hz, SCH_2), 3.55 (t, 2H, $J = 7.4$ Hz, NH_2), 1.73–1.66 (m, 2H, CH_2CH_3), 0.95 (t, 3H, $J = 7.4$ Hz, CH_3); MS (EI, m/z, %): 320 (M^+, 99), 285 (100), 244 (99), 150 (99); calcd. for $C_{16}H_{17}ClN_2OS$ (%): C, 59.90; H, 5.34; N, 8.73; found (%): C, 60.01; H, 5.55; N, 8.97.

2-Ethoxycarbomethylenethio-3-propyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4c)

Appearance: light yellow crystal; yield 62%; m.p 92–94°C; IR (KBr)ν/cm^{-1}: 1730, 1715 (C=O), 1631 (C=C), 1572 (C=N), 1496, 1471, 1435 (Ar);^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.76$ (d, 1H, $J = 9.3$ Hz, =CH), 7.41–7.23 (m, 4H, Ar), 4.23 (q, 2H, $J = 7.4$ Hz, OCH_2), 4.08 (s, 2H,

SCH_2), 3.58 (t, 2H, $J = 7.2$ Hz, NCH_2), 1.76–1.68 (m, 2H, NCH_2CH_2), 1.28 (t, 3H, $J = 7.4$ Hz, OCH_2CH_3), 0.96 (t, 3H, $J = 7.4$ Hz, CH_3); MS (EI, m/z, %): 366 (M^+, 66), 331 (100), 279 (64), 150 (74); calcd. for $C_{17}H_{19}ClN_2O_3S$ (%): C, 55.66; H, 5.22; N, 7.64; found (%): C, 55.44; H, 5.10; N, 7.82.

2-Benzylthio-3-propyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4d)

Appearance: light yellow crystal; yield 72%; m.p. 102–103°C; IR (KBr)ν/cm^{-1}: 1709 (C=O), 1632 (C=C), 1579 (C=N), 1485, 1476, 1437 (Ar); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.85$ (d, 1H, $J = 8.7$ Hz, $=CH_2$), 7.46–7.4 (m, 5H, Ph), 7.39–7.23 (m, 4H, Ar), 4.56 (s, 2H, SCH_2), 3.54 (t, 2H, $J = 7.2$ Hz, NCH_2), 1.74–1.61 (m, 2H, NCH_2CH_2), 0.93 (t, 3H, $J = 7.4$ Hz, CH_3); MS (EI, m/z, %): 370 (M^+, 12), 335 (9), 279 (6), 150 (11), 91 (100); calcd. for $C_{20}H_{19}ClN_2OS$ (%): C, 64.77; H, 5.16; N, 7.55; found (%): C, 64.62; H, 5.30; N, 7.91.

2-Ethoxycarbomethylenethio-3-i-propyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4e)

Appearance: light yellow crystal; yield 70%; m.p. 98–100°C; IR (KBr)ν/cm^{-1}: 1739, 1706 (C=O), 1631 (C=C), 1585 (C=N), 1552, 1495, 1436 (Ar);^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.74$ (d, 1H, $J = 8.4$ Hz, $=CH_2$), 7.40–7.20 (m, 4H, Ar), 4.29–4.19 (m, 1H, NCH), 4.23 (q, 2H, $J =$ 7.2 Hz, OCH_2), 4.06 (s, 2H, SCH_2), 1.51 (d, 6H, $J = 6.6$ Hz, $CH(CH_3)_2$), 1.29 (t, 3H, $J = 7.2$ Hz, CH_2CH_3); MS (EI, m/z, %): 366 (M^+, 19), 289 (31), 331 (100), 279 (17), 150 (35); calcd. for $C_{17}H_{19}Cl\ N_2O_3S$ (%): C, 55.66; H, 5.22; N, 7.64; found (%): C, 55.70; H, 5.25; N, 7.73.

2-Benzylthio-3-i-propyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4f)

Appearance: light yellow crystal; yield 67%; m.p. 83–85°C; IR (KBr)ν/cm^{-1}:1709 (C=O), 1632 (C=C), 1579 (C=N), 1485, 1476, 1437 (Ar); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.82$ (d, 1H, $J = 8.7$ Hz, =CH), 7.46–7.36 (m, 5H, Ph), 7.34–7.27 (m, 4H, Ar), 4.56 (s, 2H, SCH_2), 4.24–4.19 (m, 1H, NCH), 1.48(d, 6H, $J = 7.5$ Hz, $CH(CH_3)_2$); MS (EI, m/z, %): 370 (M^+, 29), 335 (12), 279 (21), 150 (16), 91 (100); calcd. for $C_{20}H_{19}ClN_2OS$ (%): C, 64.77; H, 5.16; N, 7.55; found (%): C, 64.86; H, 4.98; N, 7.38.

2-Ethoxycarbomethylenethio-3-butyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4g)

Appearance: light yellow crystal; yield 56%; m.p. 56–57°C; IR (KBr)ν/cm^{-1}:1729, 1708 (C=O), 1635 (C=C), 1587 (C=N), 1548, 1486,

1438 (Ar); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.72$ (d, 1H, $J = 9.9$ Hz, =CH), 7.38–7.21 (m, 4H, Ar), 4.22 (q, 2H, $J = 7.1$ Hz, OCH_2CH_3), 4.06 (s, 2H, SCH_2), 3.59 (t, 2H, $J = 7.1$ Hz, NCH_2), 1.69–1.59 (m, 2H, NCH_2CH_2), 1.41–1.33 (m, 2H, $NCH_2CH_2CH_2$), 1.28 (t, 3H, $J = 7.1$ Hz, OCH_2CH_3); 0.95 (t, 3H, $J = 7.4$ Hz, $NCH_2CH_2CH_2CH_3$); MS (EI, m/z, %): 380 (M^+, 19), 345 (100), 293 (12), 150 (35); calcd. for $C_{18}H_{21}Cl\,N_2O_3S$ (%): C, 56.76; H, 5.56; N, 7.35; found (%): C, 56.55; H, 5.39; N, 7.94.

2-Benzylthio-3-butyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4h)

Appearance: light yellow crystal; yield 66%; m.p. 97–99°C; IR (KBr)ν/cm^{-1}:1708 (C=O), 1632 (C=C), 1582 (C=N), 1532, 1483, 1439 (Ar); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.84$ (d, 1H, $J = 8.4$ Hz, =CH), 7.46–7.40 (m, 5H, Ph), 7.34–7.24 (m, 4H, Ar), 4.56 (s, 2H, SCH_2), 3.57 (t, 2H, $J = 7.4$ Hz, NH_2), 1.65–1.57 (m, 2H, NCH_2CH_2), 1.38–1.30 (m, 2H, CH_2CH_3), 0.93 (t, 3H, $J = 7.4$ Hz, CH_3); MS (EI, m/z,%): 384 (M^+, 38), 351 (28), 293 (26), 150 (20), 91 (100); calcd. for $C_{21}H_{21}ClN_2OS$ (%): C, 65.53; H, 5.50; N, 7.28; found (%): C, 65.17; H, 5.58; N, 7.70.

2-Propargylthio-3-i-butyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4i)

Appearance: light yellow crystal; yield 70%; m.p. 120–121°C; IR (KBr) ν/cm^{-1}: 3253 ($\equiv$C–H), 2125 (C$\equiv$C), 1740 (C=O), 1635 (C=C), 1582 (C=N), 1483, 1466, 1439 (Ar); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.82$ (d, 1H, $J = 9.6$ Hz, =CH), 7.43–7.23 (m, 4H, Ar), 4.11 (s, 2H, SCH_2), 3.38 (d, 2H, $J = 7.5$ Hz, NCH_2), 2.32 (t, 1H, $J = 2.7$ Hz, $\equiv$C–H), 2.12–2.07 (m, 1H, CH), 0.94 (d, 6H, $J = 6.6$Hz, $2CH_3$); MS (EI, m/z, %): 332 (M^+, 100), 317 (10), 293 (40), 150 (61), calcd. for $C_{17}H_{17}ClN_2OS$ (%): C, 61.34; H, 5.15; N, 8.42; found (%): C, 61.11; H, 5.13; N, 8.68.

2-Ethoxycarbomethylenethio-3-i-butyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4j)

Appearance: light yellow crystal; yield 59%; m.p. 93–94°C; IR (KBr)ν/cm^{-1}: 1725, 1704 (C=O), 1633 (C=C), 1579 (C=N), 1554, 1486, 1437 (Ar); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.77$ (d, 1H, $J = 9.3$ Hz, =CH), 7.41–7.23 (m, 4H, Ar), 4.22 (q, 2H, $J = 6.9$ Hz, OCH_2CH_3), 4.07 (s, 2H, SCH_2), 3.42 (d, 2H, $J = 7.2$Hz, NCH_2), 2.18–2.08 (m, 1H, NCH_2CH), 1.28 (t, 3H, $J = 7.4$ Hz, OCH_2CH_3), 0.96 (d, 3H, $J = 6.6$ Hz, $2CH_3$); MS (EI, m/z, %): 380 (M^+, 13), 345 (100), 293 (13), 150 (24), calcd. for $C_{18}H_{21}ClN_2O_3S$ (%): C, 56.76; H, 5.56; N, 7.35; found (%): C, 56.48; H, 5.65; N, 7.52.

2-Benzylthio-3-i-butyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4k)

Appearance: light yellow crystal; yield 63%; m.p. 105–107°C; IR (KBr)ν/cm^{-1}: 1709 (C=O), 1622 (C=C), 1582 (C=N), 1552, 1484, 1436 (Ar); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.86$ (d, 1H, $J = 9.3$ Hz, =CH), 7.46–7.37 (m, 5H, Ph), 7.34–7.24 (m, 4H, Ar), 4.56 (s, 2H, SCH_2), 3.38 (d, 2H, $J = 7.2$ Hz, NCH_2), 2.13–2.07 (m, 1H, CH), 0.94 (d, 6H, $J = 6.6$ Hz, $2CH_3$). MS (EI, m/z, %): 384(M^+, 38), 349 (55), 293 (67), 150 (56); calcd. for $C_{21}H_{21}ClN_2OS$ (%): C, 65.53; H, 5.50; N, 7.28; found (%): C, 65.31; H, 5.06; N, 7.61.

2-Methylthio-3-t-butyl-5-(2-chlorophenylmethylidene)-4H-imidazoli-4-one (4l)

Appearance: light yellow crystal; yield 79%; m.p. 128–129°C; IR (KBr)ν/cm^{-1}:1709 (C=O), 1629 (C=C), 1582 (C=N), 1552, 1484, 1443 (Ar); ^{1}H NMR (300 MHz, $CDCl_3$, ppm): $\delta = 8.81$ (d, 1H, $J = 9.0$ Hz, =CH), 7.42–7.27 (m, 4H, Ar), 2.68 (s, 3H, SCH_3), 1.69 (s, 9H, $3CH_3$); MS (EI, m/z, %): 308 (M^+, 18), 273 (14), 217 (100), 151 (40); calcd. for $C_{15}H_{17}ClN_2OS$ (%): C, 58.34; H, 5.55; N, 9.07; found (%): C, 58.37; H, 5.64; N, 8.87.

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