Synthesis of 1,2,4-Triazole, 1,2,4-Triazolo[3,4-*b*][1,3,4]thiadiazole and 1,2,4-Triazolo[3,4-*b*][1,3,4]thiadiazine Derivatives of Benzotriazole

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A novel series of 1-(1-carbonylmethyl-1*H*-benzotriazole) thiosemicarbazides **3a-e** was synthesized and then cyclized with sodium hydroxide to afford 1-(4-substituted-4*H*-1,2,4-triazole-3-thion-5-yl)methyl-1*H*-benzotriazoles **4a-e**, which were alkylated with ethyl iodide to 1-(3-ethylthio-4-substituted-4*H*-1,2,4-triazol-5-yl)-methyl-1*H*-benzotriazoles **5b-e**. The reaction of 1*H*-benzotriazol-1-acetic acid hydrazide (**2**) with carbon disulphide and potassium hydroxide followed by hydrazine hydrate gave 1-(4-amino-4*H*-1,2,4-triazole-3-thion-5-yl)methyl-1*H*-benzotriazole (**6**). Its subsequent condensation with carboxylic acids in the presence of phosphorus oxychloride or with phenacyl bromides afforded two series of fused heterocycles namely; 6-substituted-3-[1-(1*H*-benzotriazole)methyl]-1,2,4-triazolo[3,4-*b*][1,3,4]thiadiazoles **7a-e** and 6-substituted phenyl-3-[1-(1*H*-benzotriazole)methyl]-7*H*-1,2,4-triazolo[3,4-*b*][1,3,4]thiadiazines **8a-e** respectively. The structure of the newly synthesized compounds was elucidated by elemental analyses, ir and nmr spectra.

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The recent literature is enriched with progressive findings about the synthesis and pharmacological action of fused heterocycles. The 1*H*-benzotriazole nucleus is associated with diverse pharmacological activities such as antiinflammatory [1], antiviral [2], antifungal [3], antineoplastic [4] and antidepressant [5] effects. Furthermore, several other publications have also pointed out the value of *s*-triazolo[3,4-*b*][1,3,4]thiadiazoles [6,7]; 7*H*-*s*-triazolo-[3,4-*b*][1,3,4]thiadiazines [8] and 1,2,4-triazole-3-thiones [9-14] as biologically active nuclei.

These findings focused particular interest to incorporate thiosemicarbazides, triazoles, *s*-triazolo[3,4-*b*][1,3,4]-thiadiazoles, or 7*H*-*s*-triazolo[3,4-*b*][1,3,4]thiadiazines with 1*H*-benzotriazole in one framework with the hope to obtain compounds of better antimicrobial activity.

Chemistry.

For the synthesis of the target heterocycles, the reaction sequences outlined in the scheme were followed. Thus, ethyl 1*H*-benzotriazol-1-acetate (**1**) [1] was allowed to react with hydrazine hydrate in ethanol to give the new product 1*H*-benzotriazol-1-acetic acid hydrazide (**2**). Condensation of the acid hydrazide **2** with alkyl, aralkyl and aryl isothiocyanates [13,15] afforded a novel series of 4-alkyl, aralkyl and aryl-1-(1-carbonylmethyl-1*H*-benzotriazole) thiosemicarbazides **3a-e**. Cyclization of these thiosemicarbazides

Scheme

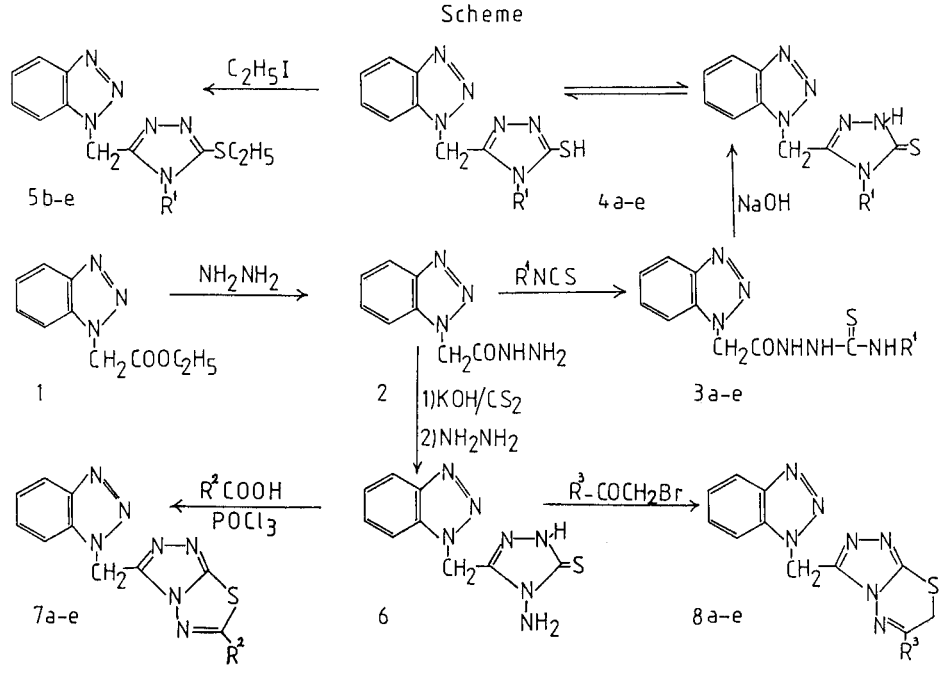

Table I

4-Alkyl, Aralkyl and Aryl-1-(1-carbonylmethyl-1*H*-benzotriazole) Thiosemicarbazides **3a-e**

Compound No.	R^1	Yield %	Mp °C	Molecular Formula	Analyses C%	H%	N%	S%
3a	*n*-C_4H_9	60	180-181	$C_{13}H_{18}N_6OS$	50.96	5.92	27.43	10.46
					51.20	6.00	27.10	10.10
3b	CH_2-C_6H_5	65	190-191	$C_{16}H_{16}N_6OS$	56.46	4.74	24.69	9.42
					56.20	4.60	24.30	9.80
3c	C_6H_5	75	184-185	$C_{15}H_{14}N_6OS$	55.20	4.32	25.75	9.82
					55.40	4.50	25.60	9.50
3d	C_6H_4-CH_3(*p*)	77	171-172	$C_{16}H_{16}N_6OS$	56.46	4.74	24.69	9.42
					56.10	4.50	24.30	9.00
3e	C_6H_4-Br(*p*)	80	191-192	$C_{15}H_{13}BrN_6OS$	44.45	3.23	20.74	7.91
					44.50	3.40	21.00	7.90

Table II

1-(4-Alkyl, Aralkyl and Aryl-4*H*-1,2,4-triazole-3-thion-5-yl)methyl-1*H*-benzotriazoles **4a-e**

Compound No.	R^1	Yield %	Mp °C	Molecular Formula	Analyses C%	H%	N%	S%
4a	*n*-C_4H_9	90	333-334	$C_{13}H_{16}N_6S$	54.15	5.59	29.14	11.12
					54.40	5.40	29.40	11.00
4b	CH_2-C_6H_5	90	210-211	$C_{16}H_{14}N_6S$	59.61	4.38	26.07	9.94
					59.40	4.50	26.20	9.60
4c	C_6H_5	95	315-316	$C_{15}H_{12}N_6S$	58.43	3.92	27.25	10.40
					58.20	3.70	26.90	10.20
4d	C_6H_4-CH_3(*p*)	98	257-258	$C_{16}H_{14}N_6S$	59.61	4.38	26.07	9.94
					59.90	4.20	26.10	9.90
4e	C_6H_4-Br(*p*)	98	268-269	$C_{15}H_{11}BrN_6S$	46.53	2.86	21.70	8.28
					46.70	3.00	21.30	8.60

Table III

1-(4-Aralkyl and Aryl-3-ethylthio-4*H*-1,2,4-triazol-5-yl)methyl-1*H*-benzotriazoles **5b-e**

Compound No.	R^1	Yield %	Mp °C	Molecular Formula	Analyses C%	H%	N%	S%
5b	CH_2-C_6H_5	85	125-126	$C_{18}H_{18}N_6S$	61.69	5.18	23.98	9.15
					62.00	5.40	23.60	9.30
5c	C_6H_5	90	152-153	$C_{17}H_{16}N_6S$	60.70	4.79	24.98	9.53
					60.90	5.00	24.70	9.40
5d	C_6H_4-CH_3(*p*)	95	179-180	$C_{18}H_{18}N_6S$	61.69	5.18	23.98	9.15
					61.50	5.00	23.70	9.30
5e	C_6H_4-Br(*p*)	95	134-135	$C_{17}H_{15}BrN_6S$	49.16	3.64	20.24	7.72
					49.40	3.80	20.50	7.50

Table IV

6-Substituted-3-[1-(1*H*-benzotriazole)methyl]-1,2,4-triazolo[3,4-*b*][1,3,4]thiadiazoles **7a-e**

Compound No.	R^2	Yield %	Mp °C	Molecular Formula	Analyses C%	H%	N%	S%
7a	CH_3	80	195-196	$C_{11}H_9N_7S$	48.70	3.34	36.14	11.82
					48.50	3.20	36.20	11.60
7b	CH_2-CH_3	85	137-138	$C_{12}H_{11}N_7S$	50.53	3.89	34.38	11.24
					50.20	3.70	34.50	11.10
7c	CH_2-C_6H_5	81	158-159	$C_{17}H_{13}N_7S$	58.78	3.77	28.22	9.23
					59.00	3.90	28.50	8.90
7d	C_6H_5	90	227-228	$C_{16}H_{11}N_7S$	57.65	3.33	29.41	9.62
					57.80	3.40	29.50	9.90
7e	3-pyridyl	90	217-218	$C_{15}H_{10}N_8S$	53.88	3.01	33.51	9.59
					54.00	3.20	33.90	9.20

Table V

6-Substituted Phenyl-3-[1-(1*H*-benzotriazole)methyl]-7*H*-1,2,4-triazolo[3,4-*b*][1,3,4]thiadiazines **8a-e**

Compound No.	R^3	Yield %	Mp °C	Molecular Formula	Analyses C%	H%	N%	S%
8a	C_6H_5	96	188-189	$C_{17}H_{13}N_7S$	58.78	3.77	28.22	9.23
					59.00	3.90	28.40	9.50
8b	C_6H_4-Br(*p*)	86	195-196	$C_{17}H_{12}BrN_7S$	47.90	2.84	23.00	7.52
					47.60	2.70	23.20	7.30
8c	C_6H_4-Cl(*p*)	87	201-202	$C_{17}H_{12}ClN_7S$	53.47	3.17	25.68	8.40
					53.10	3.00	25.90	8.70
8d	C_6H_4-CH_3(*p*)	93	172-173	$C_{18}H_{15}N_7S$	59.82	4.18	27.13	8.87
					59.60	4.00	26.90	9.10
8e	C_6H_4-OCH_3(*p*)	88	174-175	$C_{18}H_{15}N_7OS$	57.28	4.01	25.98	8.49
					57.50	4.20	25.60	8.30

Table VI

The Infrared Spectra of the Compounds **3** and **4**

Compound No.	NH	C=O	C=N	N-C=S
3a	3300, 3150	1685	--	1560, 1280, 1160, 965
3b	3330, 3240	1675	--	1550, 1285, 1165, 955
3c	3200, 3150	1700	--	1560, 1280, 1160, 955
3d	3200, 3150	1680	--	1560, 1280, 1160, 955
3e	3280, 3200	1700	--	1550, 1285, 1160, 965
4a	3140	--	1575	1540, 1270, 1155, 930
4b	3160	--	1580	1540, 1265, 1155, 930
4c	3160	--	1575	1545, 1260, 1155, 945
4d	3140	--	1575	1545, 1270, 1160, 940
4e	3150	--	1580	1545, 1270, 1160, 940

The Infrared Spectra of Compounds **5**, **7**, and **8**
C=N and C=C Mixed Stretching Vibration

5b	1610, 1600, 1590, 1510
5c	1610, 1600, 1590, 1515
5d	1610, 1600, 1595, 1505
5e	1610, 1600, 1590, 1505
7a	1610, 1590, 1510
7b	1610, 1595, 1510
7c	1600, 1590, 1510
7d	1600, 1585, 1515
7e	1610, 1585, 1510
8a	1590, 1560, 1500
8b	1585, 1560, 1505
8c	1585, 1560, 1510
8d	1595, 1550, 1510
8e	1590, 1560, 1510

with sodium hydroxide [13,16] yielded 1-(4-alkyl, aralkyl and aryl-4*H*-1,2,4-triazole-3-thion-5-yl)methyl-1*H*-benzotriazoles **4a-e** which were alkylated with ethyl iodide [13] to give 1-(4-aralkyl and aryl-3-ethylthio-4*H*-1,2,4-triazol-5-yl)methyl-1*H*-benzotriazoles **5b-e**.

The new key intermediate 1-(4-amino-4*H*-1,2,4-triazole-3-thion-5-yl)methyl-1*H*-benzotriazole (**6**) was prepared from the reaction of the acid hydrazide **2** with carbon disulphide and potassium hydroxide followed by hydrazine hydrate [17]. Condensation of the amino-1,2,4-triazole **6** with carboxylic acids in presence of phosphorus oxychloride [18] produced a series of 6-substituted-3-[1-(1*H*-benzotriazole)methyl]-1,2,4-triazolo[3,4-*b*][1,3,4]thiadiazoles **7a-e**; while its condensation with substituted phenacyl bromides [8] afforded the fused heterocycles, 6-substituted phenyl-3-[1-(1*H*-benzotriazole)methyl]-7*H*-1,2,4-triazolo[3,4-*b*][1,3,4]thiadiazines **8a-e**.

Antimicrobial Evaluation.

The antimicrobial activity of the prepared compounds **2**, **3a-e**, **4a-e**, **5b-e**, **6**, **7a-e**, and **8a-e** was determined by the agar diffusion method [19]. A 0.1% solution of the tested compounds in propylene glycol was used. The microorganisms used were *Staphylococcus aureus* NCTC 4163, *Escherichia coli* NCTC 5933, and *Candida albicans* 3501 [20]. A 0.1% streptomycin solution in propylene glycol was used as a standard. Thus, sterile nutrient agar (oxoid) was inoculated with the test organisms. Three drops of the solution of the tested compounds were separately placed in cups (8 mm diameter) cut in the agar medium. The plates were incubated at 37° for 24 hours. The resulting inhibition zones were measured.

The inhibition zones of the prepared compounds against *Staphylococcus aureus, Escherichia coli*, and *Candida albicans* were 13-16 mm; 14-17 mm; and 14-19 mm respectively; whereas the inhibition zones exhibited by streptomycin against the same organisms were 29, 25 and 13 mm respectively. Compounds **5c, 5d, 7c** were inactive against *Staphylococcus aureus*; compounds **5b, 5d** were inactive against *Escherichia coli*; whereas compounds **2, 3e, 4a, 5b** were inactive against *Candida albicans.*

It can be concluded that none of the prepared compounds were superior to streptomycin against *Staphylococcus aureus* and *Escherichia coli* while most of the prepared compounds were more active than streptomycin against *Candida albicans.*

EXPERIMENTAL

The melting points were determined in open capillary tubes and are uncorrected. The ir spectra were measured for Nujol mulls on a

Beckmann 4210-ir-spectrometer. The nmr spectra were recorded with a Varian EM-360L spectrometer at 60 MHz in hexadeuteriodimethyl sulfoxide (unless otherwise indicated) and with TMS as an internal standard. Elemental analyses were performed by the Microanalytical Centre, Cairo University, Egypt.

1*H*-Benzotriazol-1-acetic Acid Hydrazide (**2**).

Hydrazine hydrate (2.5 g, 0.05 mole) was added to a solution of ethyl 1*H*-benzotriazol-1-acetate (**1**) (2.04 g, 0.01 mole) [1] in ethanol (10 ml). The reaction mixture was heated under reflux for one hour, concentrated in vacuum, cooled and diluted with water. The precipitate obtained was filtered, washed with ice cold water, dried and recrystallized from ethanol, mp 172-173°, yield 97%; ir (nujol): 3300, 3160 (NH), 1655 (C=O), 1640 (C=N), 1545 cm^{-1} (NH); ^1H nmr: δ 4.2 (broad s, 2, NH_2, deuterium oxide exchangeable), 5.43 (s, 2, CH_2), 7.23-7.66 (m, 2, C-5, C-6 of benzotriazole), 7.76-8.21 (m, 2, C-4, C-7 of benzotriazole), 9.7 (broad s, 1, NH, deuterium oxide exchangeable).

Anal. Calcd. for $C_8H_9N_5O$: C, 50.26; H, 4.74; N, 36.63. Found: C, 50.00; H, 4.50; N, 36.40.

4-Alkyl, Aralkyl and Aryl-1-(1-carbonylmethyl-1*H*-benzotriazole) Thiosemicarbazides **3a-e**. General Procedure.

A solution containing 1*H*-benzotriazol-1-acetic acid hydrazide (**2**) (0.956 g, 0.005 mole) and the appropriate isothiocyanate (0.005 mole) in ethanol (20 ml) was heated under reflux for 15 minutes and then left at room temperature overnight. The separated product was filtered, washed with ethanol, dried and recrystallized from aqueous dioxane. The products obtained, **3a-e**, are listed in Table I. Their ir spectra are listed in Table VI; ^1H nmr of **3b**: δ 4.87 (d, 2, $CH_2C_6H_5$), 5.53 (s, 2, CH_2), 7.1-8.2 (m, 9, ArH), 8.57, 9.37, 10.4 (each broad s, 1, NH, deuterium oxide exchangeable); ^1H nmr of **3d**: δ 2.33 (s, 3, CH_3), 5.6 (s, 2, CH_2), 7.0-8.2 (m, 8, ArH), 9.8 (broad s, 2, NH, deuterium oxide exchangeable), 10.3 (broad s, 1, NH, deuterium oxide exchangeable).

1-(4-Alkyl, Aralkyl and Aryl-4*H*-1,2,4-triazole-3-thion-5-yl)methyl-1*H*-benzotriazoles **4a-e**. General Procedure.

A suspension of the appropriate 4-alkyl, aralkyl or aryl-1-(1-carbonylmethyl-1*H*-benzotriazole) thiosemicarbazide, **3a-e**, (0.001 mole) in sodium hydroxide solution (5%, 5 ml) was heated under reflux for one hour. The reaction mixture was allowed to cool, then adjusted to *p*H 6 with 10% hydrochloric acid. The precipitate formed was filtered, washed with water, dried and recrystallized from aqueous dioxane. The prepared compounds, **4a-e**, are given in Table II. Their ir spectra are listed in Table VI; ^1H nmr of **4b**: δ 5.4 (s, 2, $CH_2C_6H_5$), 5.97 (s, 2, CH_2), 7.0-8.2 (m, 9, ArH), 14.05 (s, 1, SH, deuterium oxide exchangeable); ^1H nmr of **4d**: δ 2.33 (s, 3, CH_3), 5.9 (s, 2, CH_2), 6.9-8.2 (m, 8, ArH), 14.1 (broad s, 1, SH, deuterium oxide exchangeable).

1-(4-Aralkyl and Aryl-3-ethylthio-4*H*-1,2,4-triazol-5-yl)methyl-1*H*-benzotriazoles **5b-e**. General Procedure.

The appropriate mercaptotriazole **4b-e** (0.001 mole) was dissolved in an ethanolic solution of sodium ethoxide prepared from sodium metal (0.023 g, 0.001 g-atom) in ethanol (15 ml) and then ethyl iodide (0.3 g, 0.002 mole) was added gradually to the resulting solution. The reaction mixture was heated under reflux for 2 hours, concentrated, cooled, diluted with water and left overnight. The precipitate obtained was filtered, washed with water and recrystallized from ethanol. The products obtained are listed in Table III. Their ir spectra are given in Table VI; ^1H nmr of **5b** (deuteriochloroform): δ 1.37 (t, 3, J = 7 Hz, CH_2CH_3), 3.27 (q, 2, J = 7 Hz, CH_2CH_3), 5.17 (s, 2, $CH_2C_6H_5$), 5.93 (s, 2, CH_2), 6.8-8.2 (m, 9, ArH); ^1H nmr of **5c** (deuteriochloroform): δ 1.37 (t, 3, J = 7 Hz, CH_2CH_3), 3.25 (q, 2, J = 7 Hz, CH_2CH_3), 5.93 (s, 2, CH_2), 6.73-8.2 (m, 9, ArH).

1-(4-Amino-4*H*-1,2,4-triazole-3-thion-5-yl)methyl-1*H*-benzotriazole (**6**).

To a cold stirred solution of 1*H*-benzotriazol-1-acetic acid hydrazide (**2**) (1.91 g, 0.01 mole) in absolute ethanol (250 ml) containing potassium hydroxide (0.84, 0.015 mole), carbon disulphide (1.14 g, 0.015 mole) was added gradually. The reaction mixture was stirred at room temperature for 16 hours whereupon a yellow precipitate of the corresponding potassium dithiocarbazate was separated. Dry ether (200 ml) was then added to complete the precipitation of the formed salt. The obtained product was filtered, washed with dry ether and dried in a desiccator. The salt was then suspended in 70% hydrazine hydrate (0.02 mole), stirred and heated under reflux for 2 hours. The reaction mixture was cooled, diluted with ice cold water (50 ml) and neutralized with 10% hydrochloric acid. The precipitate obtained was filtered, washed thoroughly with cold water and recrystallized from ethanol to afford **6** mp 243-244°, yield 60%; ir (nujol): 3270, 3170 (NH), 1630 (C=N), 1580 (NH), 1560, 1280, 1170, 955 cm^{-1} (N-C=S I, II, III, IV); ^1H nmr: δ 5.56 (s, 2, NH_2, deuterium oxide exchangeable), 6.1 (s, 2, CH_2), 7.1-7.7 (m, 2, C-5, C-6 of benzotriazole), 7.8-8.2 (m, 2, C-4, C-7 of benzotriazole), 13.8 (broad s, 1, SH, deuterium oxide exchangeable).

Anal. Calcd. for $C_9H_9N_7S$: C, 43.72; H, 3.67; N, 39.65; S, 12.97. Found: C, 43.30; H, 3.90; N, 39.80; S, 12.60.

6-Substituted-3-[1-(1*H*-benzotriazole)methyl]-1,2,4-triazolo[3,4-*b*][1,3,4]-thiadiazoles **7a-e**. General Procedure.

A mixture of 1-(4-amino-4*H*-1,2,4-triazole-3-thion-5-yl)methyl-1*H*-benzotriazole (**6**) (0.49 g, 0.002 mole) and the appropriate carboxylic acid (0.002 mole) in phosphorus oxychloride (4 ml) was heated under reflux at 90° for half an hour. The reaction mixture was cooled, poured gradually while stirring into an ice cold sodium bicarbonate solution. The separated product was filtered, washed thoroughly with water, dried and recrystallized from ethanol except **7b** which was recrystallized from aqueous ethanol. The compounds prepared by this method are summarized in Table IV. Their ir spectra are shown in Table VI; ^1H nmr of **7a**: δ 2.73 (s, 3, CH_3), 6.43 (s, 2, CH_2), 7.27-7.66 (m, 2, C-5, C-6 of benzotriazole), 7.8-8.2 (m, 2, C-4, C-7 of benzotriazole); ^1H nmr of **7e**: δ 6.52 (s, 2, CH_2), 7.4-8.4 (m, 4, ArH + 1 PyrH), 8.5-8.7 (m, 1, PyrH), 8.8-9.15 (m, 2, PyrH).

6-Substituted Phenyl-3-[1-(1*H*-benzotriazole)methyl]-7*H*-1,2,4-triazolo-[3,4-*b*][1,3,4]thiadiazines **8a-e**. General Procedure.

A solution of 1-(4-amino-4*H*-1,2,4-triazole-3-thion-5-yl)methyl-1*H*-benzotriazole (**6**) (0.49 g, 0.002 mole) and the appropriate phenacyl bromide derivative (0.002 mole) in absolute ethanol (20 ml) was heated under reflux for 2 hours. The reaction mixture was then cooled, adjusted to *p*H 8 by the addition of a cold saturated solution of sodium acetate and left overnight. The product which precipitated was filtered, washed with water, dried and recrystallized from ethanol. The obtained products **8a-e** are listed in Table V. Their ir spectra are given in Table VI; ^1H nmr of **8a**: δ 4.25 (s, 2, C-7 triazolothiadiazine), 6.35 (s, 2, CH_2), 7.2-8.2 (m, 9, ArH); ^1H nmr of **8d**: δ 2.4 (s, 3, CH_3), 4.2 (s, 2, C-7 triazolothiadiazine), 6.3 (s, 2, CH_2), 7.1-8.2 (m, 8, ArH); ^1H nmr of **8e**: δ 3.9 (s, 3, CH_3), 4.33 (s, 2, C-7 triazolothiadiazine), 6.38 (s, 2, CH_2), 7.0-8.2 (m, 8, ArH).

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