Reactivity of 2-substituted hydrazinecarbothioamides towards tetracyanoethylene and convenient synthesis of (5-amino-2-diazenylthiazolylmethylene)malononitrile derivatives

Alaa A. Hassan,[a,*] Nasr K. Mohamed,[a] Kamal M. A. El-Shaieb,[a] Hendawy N. Tawfeek,[a] Stefan Bräse,[b] and Martin Nieger [c]

[a] *Chemistry Department, Faculty of Science, Minia University, 61519 El-Minia, Egypt*
[b] *Institute of Organic Chemistry, Karlsruhe Institute of Technology, Fritz-Haber-Weg 6, 76131 Karlsruhe, Germany*
[c] *Laboratory of Inorganic Chemistry, Department of Chemistry, University of Helsinki P.O. Box 55 (A. I. Virtasen aukio 1), 00014 Helsinki, Finland*
E-mail: alaahassan2001@mu.edu.eg

DOI: https://doi.org/10.24820/ark.5550190.p009.872

Abstract

2-{Amino-[5-amino-2-(substituted diazenyl)thiazol-4-yl]methylene}malononitriles were synthesized from the reaction of 2-substituted hydrazinecarbothioamides with tetracyanoethylene (TCNE) to give tetracyanoethane adduct, followed by heterocyclization afforded the target compounds. The structure of (*E*)-2-{amino-[5-amino-2-(phenyldiazenyl)thiazol-4-yl]methylene}malononitrile was supported by single crystal X-ray crystallography.

Keywords: Malononitrile, thiazoles, thiosemicarbazides, tetracyanoethylene, X-ray crystallography

Introduction

Recently, thiazole derivatives have attracted a great deal of interest due to their low toxicity and broad biological activity.[1-5] For example, naturally occurring and synthetic thiazoles find applications as antibiotics and anti-inflammatories,[4-8] while selected aminothiazoles act as inhibitors of human cancer and Alzheimer`s disease.[9-11]

The syntheses of thiazoles and 2-aminothiazoles have been studied extensively,[12,13] however, the preparation of 5-aminothiazoles has not been so widely reported. Despite this, 5-aminothiazoles have received attention in a range of applications from antibiotics[14] to photosensitizers.[15]

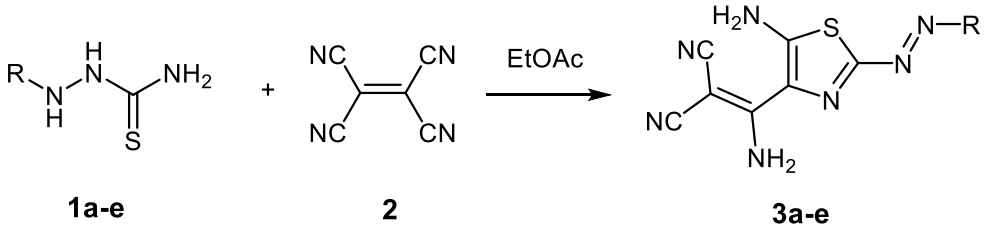
A convenient route to 5-amino-4-phenylthiazoles has been developed from *N*-acylated-glycinamides and Lawesson's reagent *via* trifluoroacetamides.[12] A flexible route to 5-amino-thiazoles has been developed based on cyclization of diamide adducts, prepared using the Ugi reaction,[16-18] in presence of Lawesson's reagent.[19] 5-Amino-3-(substituted benzylidenamino)-2-phenylimino-2,3-dihydrothiazole-4-carbonitrile is one of the products which have been isolated from the reaction of aldehyde thiosemicarbazones with tetracyanoethylene (TCNE).[20]

Mesoionic 1,2,4-triazolium-3-thiolate derivatives were synthesized from the reaction of N-substituted 2-phenylhydrazinecarbothioamides with TCNE.[21]

Herein, we report our investigation on the reaction of 2-substituted hydrazinecarbothioamides **1a**–**e** with TCNE **2** (Fig. 1) and compared with the products isolated from the reaction of N-substituted 2-phenylhydrazinecarbothioamides with TCNE **2**.

Results and Discussion

Treatment of the hydrazinecarbothioamides **1a-e** with TCNE **2** (1.1 equiv) in dry ethyl acetate at room temperature resulted in a pink coloration of the reaction solution which quickly turned reddish orange. Tentatively, the color change observed may be owed to the formation of unstable charge-transfer (CT) complexes. The mixture was stirred and then left to stand for 24 hours at room temperature, resulting in the formation of single products **3a-e** in 81-88% yields (Scheme 1).



1a-e **2** **3a-e**

R = **a:** Ph; **b:** *p*-TolSO$_2$; **c:** Bn; **d:** CH$_2$=CH-CH$_2$ **e:** *m*-ClC$_6$H$_4$

1,3	R	Yields **3a-e,** (%)
a	Ph	88
b	*p*-TolSO$_2$	84
c	Bn	83
d	CH$_2$=CH-CH$_2$	81
e	*m*-Cl-C$_6$H$_4$	86

Scheme 1. Reactions of 2-substituted hydrazinecarbothioamides **1a-e** with TCNE **2**.

The gross formula $C_{13}H_9N_7S$ represents a product from one molecule of **1a** and one molecule of TCNE **2** without elimination of any atoms. Two NH_2 groups are present in ^1H NMR (exchangeable with D_2O) as broad signals, the downfield at 10.22 ppm due to NH_2 attached to

vinyl group in **3a**, the other NH_2 resonate at 7.94 because of NH_2 attached to thiazole C5. The aromatic protons observed at 7.83-7.10 ppm. In its ^{13}C NMR spectrum, thiazole C2, C4 and C5 resonate at 161.2, 150.4 and 152.6, respectively. In the (aminomethylene)malononitrile fragment, of **3a**, the dicyanovinyl carbons C2 and C1 resonated at 164.4 and 61.6 ppm, respectively, and were in accord with the observed trends in the δ values for C-atoms in push-pull alkenes.[22,23] Further peaks at 115.6 (CN), besides the aromatic carbons support the assigned structure.

Absorption bands around 3373-3320 cm^{-1} relating to NH_2 groups appeared in IR spectra of **3a-d**. The IR spectra of **3a-e** showed two sharp absorption bands at 2220-2210 cm^{-1} (CN) and 1623-1612 cm^{-1} that assigned to C=N vibration. The absence of C=S signal in IR and ^{13}C NMR, also support the structures **3a-e**. Moreover, the structure of (*E*)-2-{amino-[5-amino-2-(phenyldiazenyl)thiazol-4-yl]methylene}malononitrile **3a** has been strongly supported by a single crystal X-ray structure analysis (Figure 1 and Tables S1-S7 in the supplementary data). The asymmetric unit of (*E*)-2-{amino-[5-amino-2-(phenyldiazenyl)thiazol-4-yl]methylene}-malononitrile **3a** ($C_{13}H_9N_7S$), confirms two independent molecules whose conformations differ primarily in the orientations of phenyl and substituted vinyl groups with respect to the thiazole ring. The X-ray structure analysis confirms a *transoid* geometry of thiazole and substituted groups with respect to the N=N double bond.

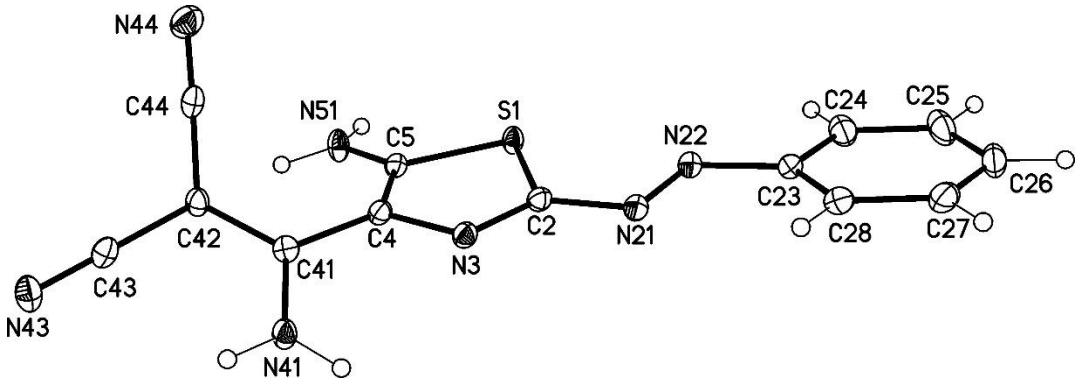
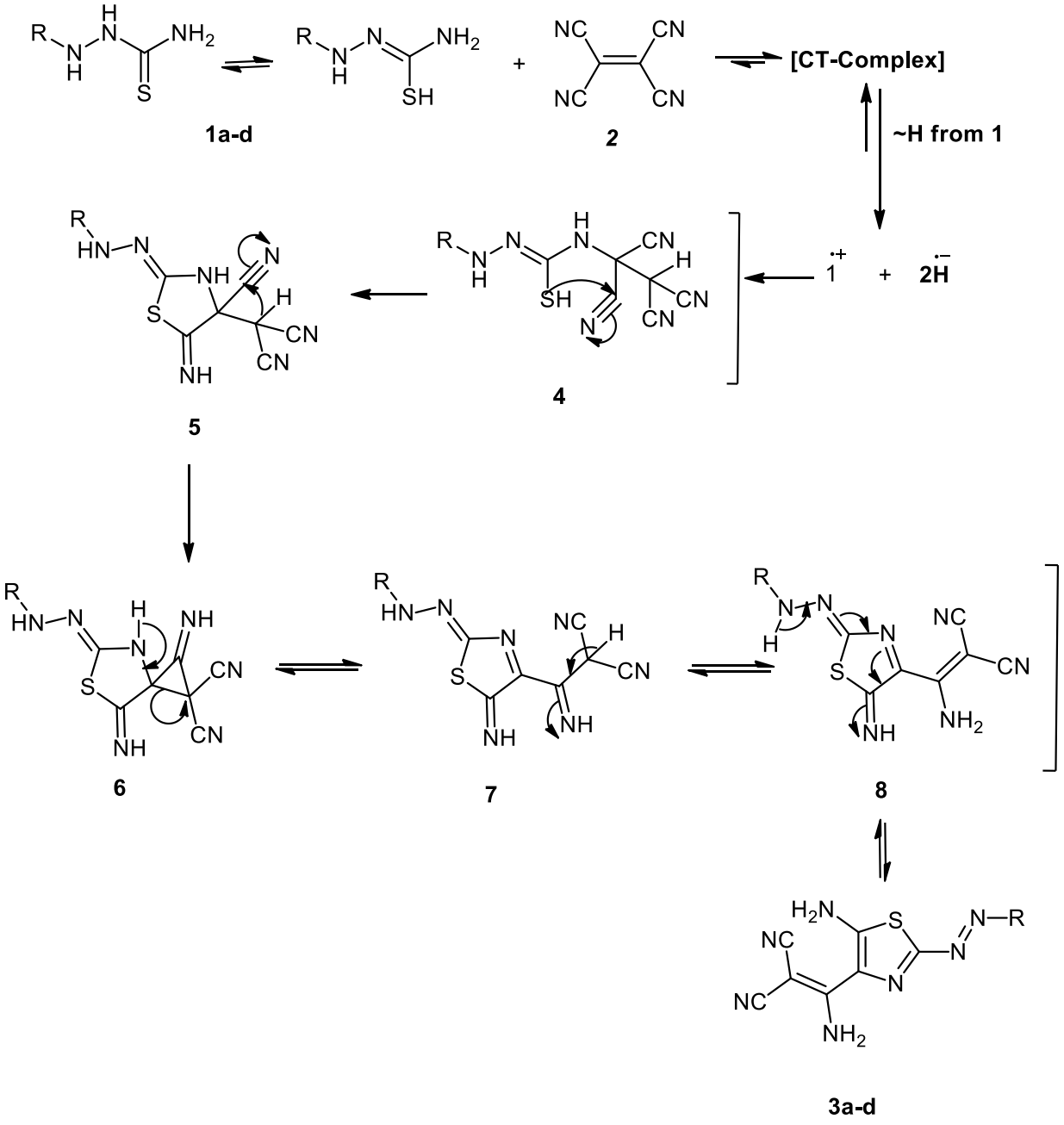


Figure 1. Molecular structure of **3a** in the crystal (TIF file). The crystallographic numbering does not reflect the systematic IUPAC numbering.

All bond lengths and angles in compound **3a** are normal. The thiazole ring is planar; mean deviation from the S1/C2/N3/C4/C5 plane 0.019 Å. The amino group and the planar phenyldiazenyl substituent are coplanar to the thiazole moiety, while the planar aminomethylenemalononitrile is twisted by 43° to the thiazole plane.

A rationale for the formation of compounds **3a-d** given in Scheme 2. Nucleophilic attack from the terminal NH_2 of **1a-d** on the C=C double bond of **2** to give the tetracyanoethane derivatives **4**; charge-transfer complexes may, but do not necessarily have to,[24] play an intermediate role. Intramolecular nucleophilic attack of SH of **4** on the C≡N triple bond and cyclization to give the intermediate **5** followed by the formation of bicyclic **6** that can open due to the proton transfer

from thiazole ring. Compound **6** can then rearrange to form **7** and **8** and finally the highly stable [amino-(5-amino-2-substituted diazenylthiazolyl)methylene]malono-nitriles **3a-e**.



Scheme 2: Mechanistic rationale for the formation of compounds **3a-e**.

Conclusions

In conclusion, novel (diazenylthiazolyl)methylene]malononitriles have been synthesized from the nucleophilic addition reactions of 2-substituted hydrazinecarbothioamides on TCNE. The products were synthesized from readily accessible starting materials using a simple experimental procedure.

Experimental Section

General. Gallenkamp melting point apparatus was used for determining the melting points; the results are uncorrected. The IR spectra (KBr discs technique) were recorded on Alpha, Bruker FT-IR and Shimadzu 408 instruments. The ^{1}H-NMR (400.13 MHz) and ^{13}C-NMR (100.6 MHz) spectra were determined on a Bruker AM 400 spectrometer; s = singlet, m = multiplet, b = broad. The ^{13}C NMR signals were assigned based on DEPT 135/90 spectra. Chemical shifts are expressed as δ in parts per million (ppm). The mass spectra (70 eV, electron impact mode) were recorded on a Finnigan MAT 312 instrument. The elemental analyses for C, H, N and S were carried out at the Microanalytical Centre, Cairo University, Egypt using an Elmyer 306. Preparative layer chromatography (PLC) used air-dried 1.0 mm thick layers of slurry-applied silica gel (Merck Pf_{254}) on glass plates 48 × 20 cm using the solvents listed.

Starting materials

The starting materials **1a-e** were prepared following published methods: **1a**,[25] **1b**,[26] **1c**[27], **1d**,[28] and **1e**[29]. Tetracyanoethylene (TCNE, **2**) was bought from Fluka (USA), recrystallized from chlorobenzene and sublimed before used. Ethyl acetate and toluene were purified according to Vogel[30] and Organikum,[31] dried and distilled. Acetonitrile (Merck) was used without further purification.

Reaction of 2-substituted hydrazinecarbothioamides 1a-e with tetracyanoethylene (2). General procedure. A solution of TCNE 2 (141 mg, 1.1 mmol) in dry EtOAc (10 mL), was added dropwise to a solution of 1a-e (1.0 mmol) in dry EtOAc (15 mL), which causes a spontaneous change of color from yellow to pink and finally to reddish orange. The mixture was stirred for 2 h, then left to stand for 24 h at room temperature. A red-orange precipitate was formed, filtered and recrystallized from acetonitrile to give pure crystals 3a-e. In case of the reaction between 1d and TCNE 2, the mixture of the reaction was subjected to PLC and using toluene/ethyl acetate (5:1) as eluent to give an intense red-orange zone from 3d. The zone was separated by using acetone and recrystallized from acetonitrile.

(*E*)-2-{Amino-5-[amino-2-(phenyldiazenyl)thiazol-4-yl]methylene}malononitrile (**3a**). Red crystals (0.259 g, 88%), mp 231-233 °C (MeCN). IR: ν_{max} (KBr)/cm^{-1} 3373-3342 (NH_2), 2215 (CN), 1620 (C=N), 1595 (Ar-C=C), 1571, 1455 (N=N) cm^{-1}. NMR: δ_H (400 MHz, DMSO-d_6) 7.10-7.12 (m, 1H, Ar-H), 7.60-7.62 (m, 2H, Ar-H), 7.80-7-83 (m, 2H, Ar-H), 7.95 (br, s, 2H, NH_2

attached to thiazole), 10.22 (br, s, 2H, NH_2). δ_c (100 MHz, DMSO-d_6) 61.6 (C-C≡N), 115.6 (CN), 124.1, 128.6, 129.7 (Ar-CH), 133.0 (Ar-C), 150.5 (thiazole-C4), 152.6 (thiazole-C5), 161.2 (thiazole-C2), 164.4 (=C-NH_2). *m/z* (%): 295 (M^+, 76), 268 (14), 190 (16), 105 (37), 77 (100). Anal. Calcd for $C_{13}H_9N_7S$ (295.32) C, 52.87; H, 3.07; N, 33.20; S, 10.86. Found: C, 53.02; H, 2.94; N, 33.33; S, 10.71%.

(*E*)-2-{Amino-5-[amino-2-(4-toluenesulfonyldiazenyl)thiazol-4-yl]methylene}malononitrile (**3b**). Red crystals (0.313 g, 84%), mp 255-257 °C (MeCN). IR: ν_{max} (KBr)/cm^{-1} 3360-3320 (NH_2), 2210 (CN), 1617 (C=N), 1580 (Ar-C=C), 1565, 1446 (N=N) cm^{-1}. δ_H (400 MHz, DMSO-d_6) 2.42 (s, 3H, CH_3), 7.52-7.55 (m, 2H, Ar-H) 7.72-7.75 (m, 2H, Ar-H), 7.98 (br, s, 2H, NH_2 attached to thiazole), 10.31 (br, s, 2H, NH_2). δ_C (100 MHz, DMSO-d_6) 21.2 (CH_3), 61.4 (C-C≡N), 115.8 (CN), 125.2, 129.5 (Ar-CH), 135.7, 140.1 (Ar-C), 149.7 (thiazole-C4), 152.6 (thiazole-C5), 161.1 (thiazole-C2), 164.2 (=C-NH_2). *m/z* (%): 373 (M^+, 12), 346 (18), 281 (100), 191 (19), 156 (16), 91 (46). Anal. Calcd for $C_{14}H_{11}N_7O_2S_2$ (373.41) C, 45.03; H, 2.97; N, 26.26; S, 17.17. Found: C, 44.89; H, 3.06; N, 26.12; S, 17.33%.

(*E*)-2-{Amino-[5-amino-2-(benzyldiazenyl)thiazol-4-yl]methylene}malononitrile (**3c**). Red-orange crystals (0.256 g, 83%), mp 242-244 °C (MeCN). IR: ν_{max} (KBr)/cm^{-1} 3366-3346 (NH_2), 2212 (CN), 1612 (C=N), 1589 (Ar-C=C), 1561, 1440 (N=N) cm^{-1}. δ_H (400 MHz, DMSO-d_6) 4.66 (s, 2H, CH_2Ph), 7.04-7.08 (m, 1H, Ar-H), 7.54-7.58 (m, 2H, Ar-H), 7.71-7.76 (m, 2H, Ar-H), 7.98 (br, s, 2H, NH_2 attached to thiazole), 10.29 (br, s, 2H, NH_2). δ_C (100 MHz, DMSO-d_6) 52.1 (CH_2Ph), 61.6 (C-C≡N), 116.0 (CN), 124.3, 128.5, 129.1 (Ar-CH), 133.6 (Ar-C), 149.7 (thiazole-C4), 152.5 (thiazole-C5), 161.2 (thiazole-C2), 164.4 (=C-NH_2). *m/z* (%) 309 (M^+, 51), 282 (26), 204 (23), 91 (100). Anal. Calcd for $C_{14}H_{11}N_7S$ (309.35) C, 54.36; H, 3.58; N, 31.69; S, 10.37. Found: C, 54.22; H, 3.66; N, 31.81; S, 10.23%.

(*E*)-2-{[2-(Allyldiazenyl)-5-aminothiazol-4-yl](amino)methylene}malononitrile (3d). Red-orange crystals (0.209 g, 81%), mp 167-169 °C (MeCN). ν_{max} (KBr)/cm^{-1} 3358-3326 (NH_2), 2210 (CN), 1615 (C=N), 1558, 1438 (N=N) cm^{-1}. δ_H (DMSO-d_6) 4.05-4.08 (m, 2H, allyl-CH_2N), 5.11-5.13 (m, 2H, allyl-CH_2=) 5.91-5.94 (m, 1H, allyl-CH=), 7.94 (br, s, 2H, NH_2 attached to thiazole), 10.16 (br, s, 2H, NH_2). δ_c (DMSO-d_6) 49.3 (allyl-CH_2N), 60.9 (C-C≡N), 115.0 (CN), 116.2 (allyl-CH_2=), 135.4 (allyl-CH=), 149.8 (thiazole-C4), 152.6 (thiazole-C5), 161.9 (thiazole-C2), 164.0 (=C-NH_2). *m/z* (%): 259 (M^+, 21), 232 (26), 154 (46), 69 (37), 41 (100). Anal. Calcd for $C_{10}H_9N_7S$ (259.29) C, 46.32; H, 3.50; N, 37.81; S, 12.37. Found: C, 46.45; H, 3.57; N, 37.93; S, 12.40%.

(*E*)-2-(Amino{5-amino-2-[(3-chlorophenyl)diazenyl]thiazol-4-yl}methylene)malononitrile (**3e**). Red-orange crystals (0.282 g, 86%), mp 248-250 °C (MeCN). IR: ν_{max} (KBr)/cm^{-1} 3365-3338 (NH_2), 2220 (CN), 1623 (C=N), 1583 (Ar-C=C), 1569, 1450 (N=N) cm^{-1}. NMR: δ_H (400 MHz, DMSO-d_6) 7.55-7.59 (m, 1H, Ar-H), 7.63-7.66 (m, 1H, Ar-H), 7.69-7-80 (m, 2H, Ar-H), 8.01 (br, s, 2H, NH_2 attached to thiazole), 10.28 (br, s, 2H, NH_2). δ_c (100 MHz, DMSO-d_6) 61.6 (C-C≡N), 115.8 (CN), 125.2, 126.3, 129.6, 130.1 (Ar-CH), 135.1, 141.2 (Ar-C), 149.7 (thiazole-C4), 153.1 (thiazole-C5), 161.2 (thiazole-C2), 164.5 (=C-NH_2). *m/z* (%): 329 (M^+, 36), 218 (28), 190 (61), 139 (43), 111 (100). Anal. Calcd for $C_{13}H_8ClN_7S$ (329.77) C, 47.35; H, 2.45; N, 29.73; S, 9.72. Found: C, 47.42; H, 2.36; N, 29.61; S, 9.83%.

Single crystal X-ray structure determination of 3a

Single crystals were obtained by recrystallization from acetonitrile. The single crystal X-ray diffraction study was carried out on a Bruker D8 Venture diffractometer with Photon100 detector at 123 K using CuKα radiation (λ = 1.54178 Å) **3a**. Direct Methods (SHELXS-97)[32] were used for structure solution and refinement was carried out using SHELXL-2014[33] (full-matrix least-squares on F^2). Hydrogen atoms were localized by difference electron density determination and refined using a riding model (H (N) free). A semi-empirical absorption correction was applied.

Compound **3a**: $C_{13}H_9N_7S$, M = 295.32 g mol^{-1}, red plates, crystal size 0.12 × 0.08 × 0.02 mm, triclinic space group, P-1 (no. 2), a = 7.3780 (4) Å, b = 7.9678 (5) Å, c =11.9389 (7) Å, α = 99.249 (2)°, β=104.589 (2)°, γ = 100.386 (2)°, V = 652.23 (7) $Å^3$, Z = 2, D_{calcd} = 1.504 Mg m^3, F(000) = 304, μ = 2.256 mm^{-1}, T = 123 K, 11384 measured reflections ($2\theta_{max}$= 144°), 2540 independent reflections [R_{int} = 0.030], 202 parameters, 4 restraints, R1 [for 2405 reflections with I > 2σ (I)] = 0.028, wR^2 (for all data) = 0.068, S = 1.06, largest diff. peak and hole = 0.266 eA^{-3}/- 0.245 eA^{-3}.

Crystallographic data (excluding structure factors) for structure reported in this work have been deposited with Cambridge Crystallographic Data center as supplementary publication no 1048447 (**3a**) Copies of the data can be obtained free of charge on application to the Director, CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: +44(1223) 336 033: e-mail: depos-it@ccdc.cam.ac.uk.

References

1. Bharti, S. K.; Nath, G.; Tilak, R.; Singh, S. K. *Eur. J. Med. Chem*. **2010**, *45*, 651-660. https://doi.org/10.1016/j.ejmech.2009.11.008
2. Jung, Y.-K.; Kim, K.-S.; Gao, Z.-G.; Gross, A. S.; Melman, N.; Jacobson, K. A.; Kim, Y.-C. *Bioorg. Med. Chem.* **2004**, *12*, 613-623. https://doi.org/10.1016/j.bmc.2003.10.041
3. Welch, J. T. *Tetrahedron* **1987**, *43*, 3123-3197. https://doi.org/10.1016/S0040-4020(01)90286-8
4. Singh, G. S.; D`hooghe, M.; De Kimpe, N. *Tetrahedron* **2011**, *67*, 1989-2012. https://doi.org/10.1016/j.tet.2011.01.013
5. Moody, C. J.; Hughes, R. A.; Thompson, S. P.; Alcaraz, L. *Chem. Commun*. **2002**, 1760-1761. https://doi.org/10.1039/B204868J
6. Crews, P.; Kakou, Y.; Quinoa, E. *J. Am. Chem. Soc*. **1988**, *110*, 4365-4368. https://doi.org/10.1039/B204868J
7. Shinagawa, H.; Yamaga, H.; Houchigai, H.; Sumita, Y.; Sunagawa, M. *Bioorg. Med. Chem.* **1997**, *5*, 601-621. https://doi.org/10.1016/S0968-0896(96)00273-8

8. Shivarama Holla, B.; Malini, K. V.; Soorryanarayana Rao, B.; Sarojini, B. K.; Suchetha Kumari, N. *Eur. J. Med. Chem.* **2003**, *38*, 313-318. https://doi.org/10.1016/S0223-5234(02)01447-2
9. Gorczynski, M. J.; Leal, R. M.; Mooberry, S. L.; Bushweller, J. H.; Brown, M. L. *Bioorg. Med. Chem.* **2004**, *12*, 1029-1036. https://doi.org/10.1016/j.bmc.2003.12.003
10. Helal, C. J.; Sanner, M. A.; Cooper, C. B.; Gant, T.; Adam, M.; Lucas, J. C.; Kang, Z.; Kupchinsky, S.; Ahlijanian, M. K.; Tate, B.; Menniti, F. S.; Kelly, K.; Peterson, M. *Bioorg. Med. Chem. Lett*. **2004**, *14*, 5521-5525. https://doi.org/10.1016/j.bmcl.2004.09.006
11. Hang, P. C.; Honek, J. F. *Bioorg. Med. Chem. Lett*. **2005**, *15*, 1471-1474. https://doi.org/10.1016/j.bmcl.2004.12.076
12. Heal, B. C. W. *In Comprehensive Heterocyclic Chemistry* III; Joule, J. A., Ed.; Katritzky, A. R., Ramsden, C. A., Scriven, E. F. V., Taylor, R. J. K., Eds.; Elsevier: Oxford, U.K., **2008**; Vol. *4*, Chapter 4.06, pp 635−754.
13. Koutentis, P. A.; Ioannidou, H. A. *In Science of Synthesis; Schaumann, E.; Ed.; Georg Thieme Verlag KG: Stuttgart, Germany*, **2010**; Vol. *11*, Product Class 18, pp 267−391.
14. Thompson, M. J.; Heal, W.; Chen, B. *Tetrahedron Lett.* **2006**, *47*, 2361-2364. https://doi.org/10.1016/j.tetlet.2006.02.004
15. Shimada, Y. *Japan Kokai Tokkyo Koho CODEN*; JXXAF JP 02113070 A2 19900425; Japan; *Chem. Abstr.* **1990**, *113*, 99405x.
16. Ugi, I. *Angew. Chem. Inter. Ed. Engl*. **1962**, *1*, 8-21. https://doi.org/10.1002/anie.196200081
17. Dömling, A.; Ugi, I. *Angew. Chem. Intern. Ed*. **2000**, *39*, 3168-3210.
18. Marcaccini, S.; Torroba, T. *Nat. Protoc*. **2007**, *2*, 632-639. https://doi.org/10.1038/nprot.2007.71
19. Thompson, M. J.; Chen, B. *Tetrahedron Lett*. **2008**, *49*, 5324-5327. https://doi.org/10.1016/j.tetlet.2008.06.067
20. Gomaa, M. A.-M.; Hassan, A. A.; Shehatta, H. S. *Heteroatom Chem*. **2006**, *17*, 261-266. https://doi.org/10.1002/hc.20198
21. Hassan, A. A.; El-Shaieb, K. M. A.; Mohamed, N. K.; Tawfeek, H. N.; Bräse, S.; Nieger, M. *Tetrahedron Lett*. **2014**, *55*, 2385-2388. https://doi.org/10.1016/j.tetlet.2014.02.107
22. Kalinowski, H. O.; Berger, S.; Brann, S. *^{13}C NMR Spektroskopic;* Georg Thieme Verlag; Stuttgart, **1984**, p. 121.
23. Gewald, K.; Schindler, R. *J. Prak. Chem.-Chemiker Zeitung* **1990**, *332*, 223-228.
24. Hassan, A. A.; Mohamed, N. K.; Shawky, A. M.; Döpp, D. *Arkivoc* **2003**, (*i*), 118-128.
25. Lee, B. W.; Lee, S. D. *Tetrahedron Lett.* **2000**, *41*, 3883-3886. https://doi.org/10.1016/S0040-4039(00)00493-7

26. Zaharia, V.; Ignat, A.; Palibroda, N.; Ngameni, B.; Kuete, V.; Fokunang, C. N.; Moungang, M. L.; Ngadjui, B. T. *Eur. J. Med. Chem.* **2010**, *45*, 5080-5085. https://doi.org/10.1016/j.ejmech.2010.08.017
27. Pluijgers, C. W.; Sijpesteijna, A. K. *Ann. Appl. Biol.* **1966**, *57*, 465-473. https://doi.org/10.1016/j.ejmech.2010.08.017
28. Forster, M. O.; Saville, W. B. *J. Chem. Soc. Trans.* **1920**, *117*, 753-761. https://doi.org/10.1039/CT9201700753
29. Parikh, P. M.; Deliwali, C. V. *Indian J. Chem.* **1965**, *3*, 45-46.
30. Vogel, A. I. A. *Text Book of Practical Organic Chemistry 3rd* (*ed*.) Longman, London, **1957.**
31. Organikum "*Organisch Chemistry Grundpraktikum"* VEB Deutscher Verlag der Wissenschaften, Berlin **1973**.
32. Sheldrick, G. M. *Acta Crystallogr., Sect. A* **2008**, *A64*, 112-122. https://doi.org/10.1107/S0108767307043930
33. Sheldrick, G. M. *Acta Crystallogr., Sect. C* **2015**, *C71*, 3-8. https://doi.org/10.1107/S2053229614024218

