Tetrahedron 66 (2010) 2700–2704

Contents lists available at ScienceDirect

Tetrahedron

journal homepage: www.elsevier.com/locate/tet

Synthesis and single-crystal X-ray diffraction analysis of new heterocyclic coloured materials. 3-Arylazo-8*H*-imidazo[1,2-*b*] pyrazolo[4,3-*d*]pyridazines

Thoraya A. Farghaly, Ahmad Sami Shawali *

Department of Chemistry, Faculty of Science, University of Cairo, Giza 12613, Egypt

ARTICLE INFO

Article history:
Received 24 October 2009
Received in revised form 26 December 2009
Accepted 1 February 2010
Available online 4 February 2010

Keywords:
Heterocycles
Azo dyes
Hydrazonoyl halides
Formazans
Hydrazones

ABSTRACT

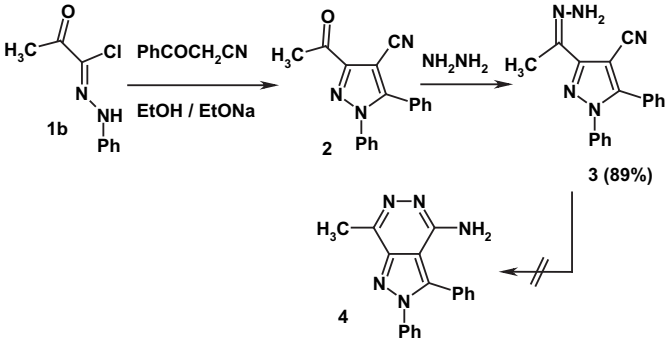
A simple synthetic strategy is described for the hitherto unreported 3-arylazo-8*H*-imidazo[1,2-*b*]pyrazolo[4,3-*d*]pyridazines **7** is described based on the reaction of 3-acetyl-4-cyano-1,5-diphenylpyrazole hydrazone **3** with the hydrazonoyl halides **1a–l**. The structures of such dyes were confirmed by spectroscopic and X-ray crystallographic analyses. The mechanism of formation of such compounds was also discussed.

1. Introduction

In continuation of our studies dealing with the utility of hydrazonoyl halides as precursors for synthesis of various heterocyclic systems[1–10] and their aryl- and hetaryl-azo dyes,[11] we wish to report herein a facile synthesis of 3-arylazo-8*H*-imidazo[1,2-*b*]pyrazolo[4,3-*d*]pyridazines that have not been reported hitherto. Our interest in synthesis of such new azo dyes is due to the fact that many arylazo derivatives of various heterocyclic systems were found useful in the fields of material sciences and theoretical chemistry.[12] For example, in addition to their use as dyes in various fields such as dyeing of textile fibres, coloured plastics, biological-medical studies and advanced applications in organic synthesis,[13] they are used in various fields such as printing, electronic photography, colour formers, liquid crystal displays laser technology, data storage and solar energy conversion.[14]

2. Results and discussion

The required hydrazonoyl halides **1a–l**[15–17] and 3-acetyl-4-cyano-1,5-diphenylpyrazole **2**[18] were prepared as previously reported. Hydrazinolysis of the latter pyrazole derivative **2** with hydrazine hydrate in refluxing ethanol was found to give the respective hydrazone derivative **3** (Scheme 1). All attempts to get the cyclized product, namely the pyrazolo[3,4-*d*]pyridazine derivative **4**, failed, however (Scheme 1). This finding seems to be compatible with other literature reports,[19] which indicated that hydrazinolysis of 3-acetyl-4-cyanopyrazole derivatives afforded in such cases the respective hydrazones.



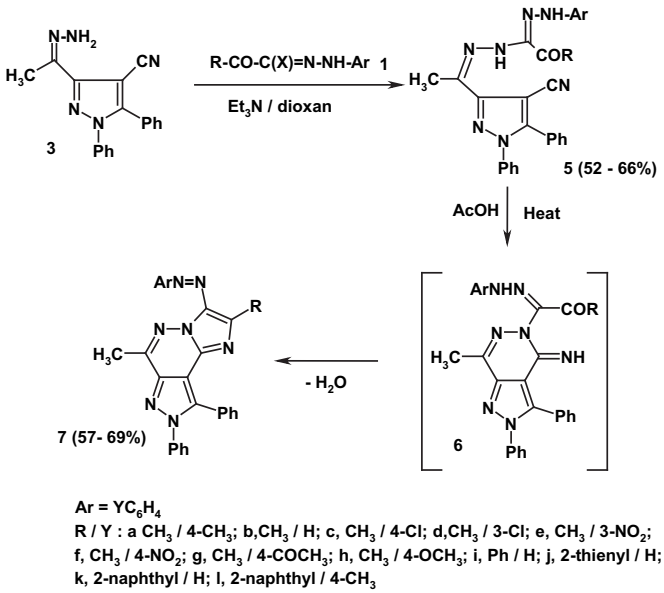
Scheme 1. Synthesis of compound **3**.

Next, reactions of **3** with various hydrazonoyl halides were examined. In our hands, it was found that the products of such reactions depend on the structure of the hydrazonoyl halides used. For example, when equimolar quantities of **3** and each of the hydrazonoyl halides **1a–g** were refluxed in dioxan in the presence of triethylamine, a single product was obtained in each case as evidenced by TLC analysis of the crude product. The results of both

* Corresponding author.
E-mail address: as_shawali@mail.com (A.S. Shawali).

0040-4020/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tet.2010.02.012

microanalyses and spectral data (MS, IR and ^{1}H NMR) of the isolated products indicated that the products isolated from such reactions are the respective substitution products namely the 1,2-dihydroformazan derivatives **5a**–**g** (Scheme 2). On the other hand, similar reactions of **3** with each of the hydrazonoyl halides **1h**–**l** were found to yield the arylazo derivatives **7h**–**l** (Scheme 2). In such cases, it seems that the initially formed substitution intermediates **5h**–**l** underwent in situ cyclization to give the corresponding arylazo derivatives **7h**–**l** as end products.



Scheme 2. Reaction of compound **3** with hydrazonoyl halides.

When each of the hydrazone derivatives **5a**–**g** was refluxed in glacial acetic acid, it underwent dehydrative cyclization and afforded the respective 3-arylazo-8*H*-imidazo[1,2-*b*]pyrazolo[4,3-*d*]pyridazines **7a**–**g** (Scheme 2).

The electronic absorption spectra of compounds **7a**–**l** were of typical azo chromophore[12,20–22] and they are depicted in Table 1. As shown each compound exhibits two bands in the regions 455–404 and 314–259 nm. The spectra of compound **7j**, taken as a typical example of the series studied, in different solvents of different polarity, showed little, if any, change. These data are similar to those of typical azo chromophore and indicate that compounds **7a**–**l** exist predominantly in the assigned azo structure.

Finally, to provide a conclusive evidence for the assigned structure **7**, we turned to X-ray crystallographic analysis. The ORTEP drawing of **7i** isolated from reaction of **3** with **1i**, taken as a typical example of the series prepared, is shown in Figure 1 with selected bond distances and bond angles depicted in Table 2.[23] This ORTEP indicates that the products isolated from either thermal acidic cyclization of the hydrazone derivatives **5a**–**g** or the reactions of **3** with **1h**–**l** have the assigned structure **7**. In addition, the foregoing results suggest that the reactions leading to **7** are site selective and proceed *via* the intermediates **5** and **6** depicted in Scheme 2.

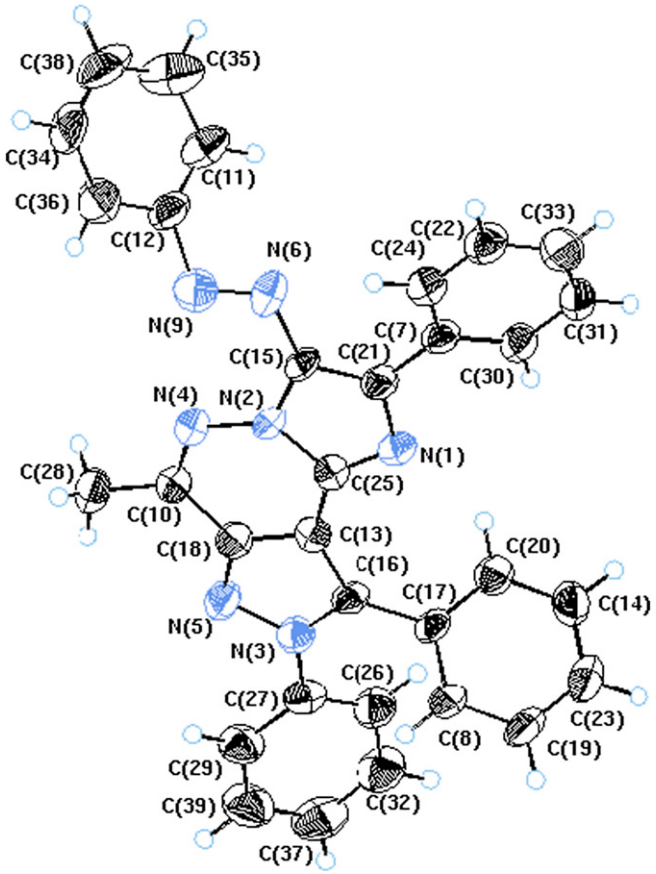


Figure 1. ORTEP plot of the molecular structure of compound **7i**. Notice the crystallographic numbering differs from the IUPAC systematic numbering used in nomenclature. Selected bond distances and bond angles are shown in Table 2.

Table 1
Electronic absorption spectra of compounds **7a**–**l** in dioxan

Compd. no.	λ_{max} (log ε) nm
7a	436 (5.11), 266 (5.40)
7b	440 (3.93), 314 (4.14), 227 (4.51)
7c	441 (4.19), 275 (4.27), 250 (4.66)
7d	404 (4.20), 275 (4.48), 251 (4.82)
7e	455 (4.65), 259 (5.41)
7f	430 (4.88), 292 (4.69), 277 (4.69), 250 (5.15)
7g	425 (4.62), 295 (4.82)
7h	405 (4.46), 298 (5.01), 255 (4.62)
7i	408 (4.54), 300 (4.62), 249 (4.82)
7j[a]	435 (4.51), 310 (4.65)
7k	412 (4.74), 290 (5.02), 258 (5.41)
7l	430 (4.32), 300 (4.68)

[a] Solvent: λ_{max} (log ε): acetic acid 441 (4.36), 309 (4.60); chloroform 436 (4.87), 313 (5.10); DMF 437 (4.78), 311 (5.01); ethanol 435 (4.44), 308 (4.66).

Table 2
Selected bond lengths and bond angles in the ORTEP of compound **7i** in the crystal. The crystallographic numbering does not reflect systematic numbering

Bond length, Å	Bond length, Å	Bond length, Å
N1–C21, 1.372	N5–N3, 1.376	C11–H11, 0.960
C21–C15, 1.377	N3–C16, 1.367	C14–H14, 0.960
C15–N2, 1.405	C16–C13, 1.389	N1–C25, 1.327
N2–N4, 1.387	C13–C25, 1.413	C22–H22, 0.960
N4–C10, 1.303	C25–N1, 1.327	C11–C12, 1.369
C10–C18, 1.457	C25–N2, 1.389	C14–C23, 1.364
C18–N5, 1.335	C18–C13, 1.403	C23–H23, 0.960
Angle (ω)	**Angle (ω)**	**Angle (ω)**
C21–N1–C25, 106.0	C21–C7–C24, 123.9	N9–C12–C36, 117.6
N4–N2–C15, 126.4	C21–C7–C30, 118.9	C11–C12–C36, 119.6
N4–N2–C25, 127.5	C24–C7–C30, 117.2	C16–C13–C18, 105
C15–N2–C25, 105.9	C17–C8–C19, 119.7	C16–C13–C25, 137.2
N5–N3–C16, 113.5	N6–N9–C12, 111.3	C18–C13–C25, 117.8
N5–N3–C27, 116.5	N4–C10–C18, 119.6	C20–C14–C23, 120.6
C16–N3–C27, 129.7	N4–C10–C28, 118.4	N2–C15–N6, 128.6
N2–N4–C10, 117.6	C18–C10–C28, 122.0	N2–C15–C21, 105.6
N3–N5–C18, 102.7	C12–C11–C35, 120.1	N6–C15–C21, 124.8
N9–N6–C15, 117.9	N9–C12–C11, 122.3	N3–C16–C13, 105.4

3. Conclusion

In summary, a convenient synthetic strategy for the title new 3-arylazo-8*H*-imidazo[1,2-*b*]pyrazolo[4,3-*d*]pyridazines was described. Their characterization and absorption spectra were studied and discussed.

4. Experimental

4.1. General

Melting points were determined on a Gallenkamp apparatus. IR spectra were recorded in potassium bromide using Perkin Elmer FTIR 1650 and Pye-Unicam SP300 infrared spectrophotometers. The ^{1}H and ^{13}C NMR spectra were recorded in deuterated chloroform or deuterated dimethyl sulfoxide on a Varian Mercury VXR-300 spectrometer (300 MHz for ^{1}H NMR and 75 MHz for ^{13}C NMR). Mass spectra were recorded on a GCMS-QP 1000 EX Shimadzu and GCMS 5988-A HP spectrometers. Electronic absorption spectra were recorded on Perkin–Elmer Lambada 40 spectrophotometer. Elemental analyses were carried out at the Microanalytical Laboratory of Cairo University, Giza, Egypt. The starting compounds hydrazonoyl halides **1** and the pyrazole derivative **2** were prepared as previously described.[15–18]

4.2. Crystallographic analysis

The crystals were mounted on a glass fibre. All measurements were performed on an ENRAF NONIUS FR 590. The data were collected at a temperature of 25 °C using the ω scanning technique to a maximum of a 20 of 22.986°. The structure was solved by direct method using SIR 92 and refined by full-matrix least squares. Non-hydrogen atoms were refined anisotropically. Hydrogen atoms were located geometrically and were refined isotropically.

4.2.1. Crystal data. For compound **7i**: $C_{32}H_{23}N_7$, M=505.585, triclinic, a=8.9652 (5), b=9.5090 (5), c=15.5928 (11) Å, v=1258.42 (13), α=72.527 (2)°, γ=83.827 (2)°, β=84.947 (2)°, space group: P-1, Z=2, D_x=1.334 Mg m^{-3} reflection 6634 measured, θ_{max}=25.02°. Figure 1 illustrates the structure as determined.[23]

4.3. Preparation of 3-acetyl-4-cyano-1,5-diphenylpyrazole hydrazone (3)

A mixture of **2** (1.44 g, 5 mmol) and hydrazine hydrate (5 mL) in absolute ethanol (15 mL) was heated to reflux for 5 h, then cooled. The solid formed was collected by filtration and recrystallized from ethanol to give compound **3** as yellow crystals (1.33 g, 89%). Mp 154–156 °C. ^{1}H NMR (DMSO-d_6, 300 MHz) δ 2.10 (s, 3H, CH_3), 5.52 (s, 2H, NH_2), 7.30–7.48 (m, 10H, Ar–H); IR (KBr) ν_{max} 3420, 3318, 2227, 1590, 1537, 1499 cm^{-1}. MS m/z (%) 302 (M^++1, 4), 301 (M^+, 22), 300 (32), 180 (7), 91 (3), 77 (100). Anal. Calcd for $C_{18}H_{15}N_5$ (301.35): C, 71.74; H, 5.02; N, 23.24. Found: C, 71.65; H, 5.00; N, 23.13%.

4.4. Reaction of compound 3 with hydrazonoyl halides 1

To a mixture of **3** (0.75 g, 2.5 mmol) and the appropriate hydrazonoyl halide **1a–g** (2.5 mmol of each) in dioxan (20 mL) was added triethylamine (0.35 mL) and the mixture was heated to reflux for 20 h, then cooled. The solution was poured onto ice and concentrated hydrochloric acid. The solid produced was collected by filtration and crystallized from the appropriate solvent to give the corresponding compounds **5a–g**, respectively.

When the above procedure was repeated using **1h–l** in place of **1a–g**, the respective 3-arylazo derivatives **7h–l** were obtained. The products **5a–g** and **7h–l** together with their physical constants are listed below.

*4.4.1. 3-Acetyl-5-(4-methylphenyl)-1-[1-(4-cyano-1,5-diphenyl-pyrazol-3-yl)ethylidene]-1,2-dihydroformazan (**5a**).* Dark yellow solid (0.78 g, 66%), mp 226–228 °C (ethanol). ^{1}H NMR (DMSO-d_6, 300 MHz) δ 2.45 (s, 3H, CH_3), 2.49 (s, 3H, CH_3), 2.57 (s, 3H, CH_3), 7.38–7.49 (m, 10H, ArH), 7.50 (d, J=9 Hz, 2H, ArH), 8.13 (d, J=9 Hz, 2H, ArH), 9.37 (s, 1H, NH), 11.31 (s, 1H, NH); IR (KBr) ν_{max} 3430, 3061, 2233, 1670, 1597, 1527, 1496 cm^{-1}. MS m/z (%), 476 (M^++1, 14), 475 (M^+, 33), 105 (53), 91 (75), 77 (100). Anal. Calcd for $C_{28}H_{25}N_7O$ (475.56): C, 70.72; H, 5.30; N, 20.62. Found: C, 70.60; H, 5.16; N, 20.49%.

*4.4.2. 3-Acetyl-5-phenyl-1-[1-(4-cyano-1,5-diphenyl-pyrazol-3-yl)ethylidene]-1,2-dihydroformazan (**5b**).* Dark orange solid (0.71 g, 62%), mp 238–240 °C (ethanol). ^{1}H NMR (DMSO-d_6, 300 MHz) δ 2.42 (s, 3H, CH_3), 2.61 (s, 3H, CH_3), 7.27–7.89 (m, 15H, ArH), 9.18 (s, 1H, NH), 10.84 (s, 1H, NH); IR (KBr) ν_{max} 3425, 3271, 2229, 1674, 1624, 1596, 1496 cm^{-1}. MS m/z (%) 461 (M^+, 31), 92 (46), 84 (34), 77 (100). Anal. Calcd for $C_{27}H_{23}N_7O$ (461.53): C, 70.27; H, 5.02; N, 21.24. Found: C, 70.16; H, 5.29; N, 21.03%.

*4.4.3. 3-Acetyl-5-(4-chlorophenyl)-1-[1-(4-cyano-1,5-diphenyl-pyrazol-3-yl)ethylidene]-1,2-dihydroformazan (**5c**).* Orange solid (0.80 g, 65%), mp 110–112 °C (dioxan/ethanol). ^{1}H NMR (DMSO-d_6, 300 MHz) δ 2.42 (s, 3H, CH_3), 2.60 (s, 3H, CH_3), 7.29–7.51 (m, 10H, ArH), 7.52 (d, J=8 Hz, 2H, ArH), 7.82 (d, J=8 Hz, 2H, ArH), 9.18 (s, 1H, NH), 10.83 (s, 1H, NH); IR (KBr) ν_{max} 3427, 3310, 2228, 1672, 1624, 1593, 1493 cm^{-1}. Anal. Calcd for $C_{27}H_{22}ClN_7O$ (495.98): C, 65.39; H, 4.47; N, 19.77. Found: C, 65.22; H, 4.19; N, 19.65%.

*4.4.4. 3-Acetyl-5-(3-chlorophenyl)-1-[1-(4-cyano-1,5-diphenyl-pyrazol-3-yl)ethylidene]-1,2-dihydroformazan (**5d**).* Dark orange solid (0.67 g, 54%), mp 200–202 °C (ethanol). ^{1}H NMR (DMSO-d_6, 300 MHz) δ 2.42 (s, 3H, CH_3), 2.61 (s, 3H, CH_3), 7.24–7.82 (m, 14H, ArH), 9.21 (s, 1H, NH), 10.87 (s, 1H, NH); IR (KBr) ν_{max} 3442, 3310, 2227, 1674, 1620, 1593, 1495 cm^{-1}. MS m/z (%) 498 (M^++2, 5), 497 (M^++1, 16), 496 (M^+, 13), 495 (40), 479 (33), 477 (49), 448 (50), 356 (13), 111 (33), 77 (100). Anal. Calcd for $C_{27}H_{22}ClN_7O$ (495.98): C, 65.39; H, 4.47; N, 19.77. Found: C, 65.59; H, 4.61; N, 19.50%.

*4.4.5. 3-Acetyl-5-(3-nitrophenyl)-1-[1-(4-cyano-1,5-diphenyl-pyrazol-3-yl)ethylidene]-1,2-dihydroformazan (**5e**).* Dark red solid (0.66 g, 52%), mp 240–242 °C (dioxan/ethanol). ^{1}H NMR (DMSO-d_6, 300 MHz) δ 2.43 (s, 3H, CH_3), 2.50 (s, 3H, CH_3), 7.36–8.13 (m, 14H, ArH), 9.25 (s 1H, NH), 11.06 (s, 1H, NH); IR (KBr) ν_{max} 3427, 3061, 2227, 1697, 1618, 1595, 1496 cm^{-1}. Anal. Calcd for $C_{27}H_{22}N_8O_3$ (506.53): C, 64.02; H, 4.38; N, 22.12. Found: C, 63.79; H, 4.52; N, 22.46%.

*4.4.6. 3-Acetyl-5-(4-nitrophenyl)-1-[1-(4-cyano-1,5-diphenyl-pyrazol-3-yl)ethylidene]-1,2-dihydroformazan (**5f**).* Dark orange solid (0.72 g, 57%), mp >300 °C (dioxan/ethanol). ^{1}H NMR (DMSO-d_6, 300 MHz) δ 2.22 (s, 3H, CH_3), 2.63 (s, 3H, CH_3), 7.04 (d, J=9 Hz, 2H, ArH), 7.21 (d, J=9 Hz, 2H, ArH), 7.36–7.78 (m, 10H, ArH), 9.13 (s 1H, NH), 10.13 (s, 1H, NH); IR (KBr) ν_{max} 3316, 3063, 2228, 1678, 1593, 1545, 1496 cm^{-1}. Anal. Calcd for $C_{27}H_{22}N_8O_3$ (506.53): C, 64.02; H, 4.38; N, 22.12. Found: C, 64.23; H, 4.19; N, 21.88%.

*4.4.7. 3-Acetyl-5-(4-acetylphenyl)-1-[1-(4-cyano-1,5-diphenyl-pyrazol-3-yl)ethylidene]-1,2-dihydroformazan (**5g**).* Orange solid (0.70 g, 56%), mp 244–246 °C (dioxan). ^{1}H NMR (DMSO-d_6, 300 MHz) δ 2.43 (s, 3H, CH_3), 2.56 (s, 3H, CH_3), 2.65 (s, 3H, CH_3), 7.35–7.88 (m, 10H, ArH), 7.91 (d, J=8 Hz, 2H, ArH), 8.11 (d, J=8 Hz, 2H, ArH), 9.27 (s, 1H, NH), 11.12 (s, 1H, NH); IR (KBr) ν_{max} 3440,

3304, 2229, 1685, 1670, 1595, 1496 cm^{-1}. Anal. Calcd for $C_{29}H_{25}N_7O_2$ (503.57): C, 69.17; H, 5.00; N, 19.47. Found: C, 68.98; H, 4.85; N, 19.22%.

*4.4.8. 2,6-Dimethyl-3-[4-methoxyphenylazo]-8,9-diphenyl-imidazo-[1,2-b]pyrazolo[4,3-d]pyridazine (**7h**).* Red solid (0.71 g, 60%), mp >300 °C (dioxan/ethanol). ^1H NMR (DMSO-d_6, 300 MHz) δ 2.29 (s, 3H, CH_3), 2.37 (s, 3H, CH_3), 3.68 (s, 3H, OCH_3), 7.12–7.44 and 7.83–7.86 (m, 10H, ArH), 7.45 (d, *J*=7 Hz, 2H, ArH), 7.55 (d, J=8 Hz, 2H, ArH); IR (KBr) ν_{max} 1587, 1526, 1494 cm^{-1}. MS *m*/*z* (%) 474 (M^++1, 25), 473 (M^+, 76), 444 (32), 351 (16), 338 (10), 287 (22), 180 (25), 135 (14), 107 (29), 92 (14), 77 (100). Anal. Calcd for $C_{28}H_{23}N_7O$ (473.54): C, 71.02; H, 4.90; N, 20.71. Found: C, 70.93; H, 4.58; N, 20.46%.

*4.4.9. 6-Methyl-3-phenylazo-2,8,9-triphenyl-imidazo[1,2-b]pyrazolo-[4,3-d]pyridazine (**7i**).* Dark orange crystals (0.85 g, 67%), mp 230–232 °C (dioxan). ^1H NMR (DMSO-d_6, 300 MHz) δ 2.56 (s, 3H, CH_3), 7.43–8.22 (m, 20H, ArH); IR (KBr) ν_{max} 1595, 1537, 1492 cm^{-1}. ^{13}C NMR (DMSO-d_6, 300 MHz) δ 17.6, 109.1, 114.0, 120.6, 120.7, 121.8, 125.6, 126.2, 127.0, 128.1, 128.2, 128.8, 129.1, 129.2, 129.3, 129.4, 129.5, 130.3, 133.3, 138.2, 138.9, 148.0, 150.1, 153.5. MS *m*/*z* (%) 505 (M^+, 19), 504 (18), 476 (11), 252 (3), 180 (7), 77 (100). Anal. Calcd for $C_{32}H_{23}N_7$ (505.59): C, 76.02; H, 4.59; N, 19.39. Found: C, 76.11; H, 4.42; N, 19.25%.

*4.4.10. 6-Methyl-3-phenylazo-8,9-diphenyl-2-(2-thienyl)-imidazo-[1,2-b]pyrazolo[4,3-d]pyridazine (**7j**).* Red solid (0.84 g, 66%), mp 128–130 °C (ethanol/dioxan). ^1H NMR (DMSO-d_6, 300 MHz) δ 2.49 (s, 3H, CH_3), 7.21–7.55 (m, 18H, ArH); IR (KBr) ν_{max} 1597, 1495, 1480 cm^{-1}. MS *m*/*z* (%) 511 (M^+, 1), 362 (7), 347 (12), 285 (3), 180 (6), 118 (6), 111 (28), 93 (8), 77 (100). Anal. Calcd for $C_{30}H_{21}N_7S$ (511.61): C, 70.43; H, 4.14; N, 19.16. Found: C, 70.11; H, 4.32; N, 19.25%.

*4.4.11. 6-Methyl-3-phenylazo-8,9-diphenyl-2-(2-naphthyl)-imidazo-[1,2-b]pyrazolo[4,3-d]pyridazine (**7k**).* Red crystals (0.96 g, 69%), mp 260–262 °C (ethanol/dioxan). ^1H NMR (DMSO-d_6, 300 MHz) δ 2.82 (s, 3H, CH_3), 7.51–7.74 (m, 16H, ArH), 7.90 (d, *J*=8 Hz, 2H, ArH), 8.32 (d, *J*=8 Hz, 2H, ArH), 8.81 (s, 1H, naphthoyl-H); IR (KBr) ν_{max} 1597, 1494, 1467 cm^{-1}. MS *m*/*z* (%) 556 (M^++1, 9), 555 (M+, 24), 526 (15), 466 (15), 180 (15), 164 (12), 93 (10), 77 (100). Anal. Calcd for $C_{36}H_{25}N_7$ (555.65): C, 77.82; H, 4.54; N, 17.65. Found: C, 77.60; H, 4.33; N, 17.42%.

*4.4.12. 6-Methyl-3-(4-methylphenylazo)-8,9-diphenyl-2-(2-naphthyl)-imidazo[1,2-b]pyrazolo[4,3-d]pyridazine (**7l**).* Red solid (1.02 g, 72%), mp 258–260 °C (dioxan). ^1H NMR (DMSO-d_6, 300 MHz) δ 2.46 (s, 3H, CH_3), 2.68(s, 3H, CH_3), 7.37–8.17 (m, 22H, ArH), 8.93 (s, 1H, naphthoyl-H); IR (KBr) ν_{max} 1600, 1495, 1480 cm^{-1}. MS *m*/*z* (%) 570 (M^++1, 7), 569 (M+, 13), 555 (34), 270 (10), 180 (25), 141 (10), 114 (12), 77 (100). Anal. Calcd for $C_{37}H_{27}N_7$ (569.67): C, 78.01; H, 4.78; N, 17.21. Found: C, 77.90; H, 4.35; N, 17.00%.

4.5. Cyclization of compounds 5a–g

A solution of compound **5a–g** (1 mmol) in glacial acetic acid (10 mL) was refluxed for 15 h. After cooling the solution was poured into ice and sodium acetate, the precipitate formed was filtered off and crystallized from the appropriate solvent to give compounds **7a–g**

*4.5.1. 2,6-Dimethyl-3-[4-methylphenylazo]-8,9-diphenyl-imidazo[1,2-b] pyrazolo[4,3-d]pyridazine (**7a**).* Brown solid (0.23 g, 51%), mp >300 °C (dioxan/ethanol). ^1H NMR (DMSO-d_6, 300 MHz) δ 1.69 (s, 3H, CH_3), 2.49 (s, 3H, CH_3), 2.61 (s, 3H, CH_3), 7.02–7.48 (m, 14H, ArH); IR (KBr) ν_{max} 1594, 1526, 1484 cm^{-1}. MS *m*/*z* (%) 458 (M^++1, 1.3), 457 (M^+, 3), 180 (8), 119 (6), 105 (38), 91 (39), 77 (100). Anal. Calcd for $C_{28}H_{23}N_7$ (457.54): C, 73.50; H, 5.07; N, 21.43. Found: C, 73.26; H, 5.30; N, 21.33%.

*4.5.2. 2,6-Dimethyl-3-[phenylazo]-8,9-diphenyl-imidazo[1,2-b] pyrazolo [4,3-d]pyridazine (**7b**).* Dark orange solid (0.24 g, 55%), mp 220–222 °C (dioxan). ^1H NMR (DMSO-d_6, 300 MHz) δ 2.32 (s, 3H, CH_3), 2.62 (s, 3H, CH_3), 7.23–8.06 (m, 15H, ArH); IR (KBr) ν_{max} 1594, 1492, 1474 cm^{-1}. MS *m*/*z* (%) 444 (M^++1,6), 443 (M^+, 8), 141 (12), 129 (12), 111 (36), 92 (10), 83 (15), 77 (100). Anal. Calcd for $C_{27}H_{21}N_7$ (443.52): C, 73.12; H, 4.77; N, 22.11. Found: C, 73.00; H, 4.25; N, 21.93%.

*4.5.3. 2,6-Dimethyl-3-[4-chlorophenylazo]-8,9-diphenyl-imidazo[1,2-b] pyrazolo[4,3-d]pyridazine (**7c**).* Pink solid (0.21 g, 43%), mp180–182 °C (ethanol). ^1H NMR ($CDCl_3$, 300 MHz) δ 2.07 (s, 3H, CH_3), 2.69 (s, 3H, CH_3), 7.32–7.50 (m, 14H, ArH); IR (KBr) ν_{max} 1594, 1523, 1445 cm^{-1}. MS *m*/*z* (%) 479 (M^++1, 16), 478 (M^+, 51), 381 (11), 245 (15), 141 (16), 128 (11), 113 (24), 111 (29), 91 (16), 77 (100). Anal. Calcd for $C_{27}H_{20}ClN_7$ (477.96): C, 67.85; H, 4.22; N, 20.51. Found: C, 67.64; H, 4.03; N, 20.29%.

*4.5.4. 2,6-Dimethyl-3-[3-chlorophenylazo]-8,9-diphenyl-imidazo[1,2-b] pyrazolo[4,3-d]pyridazine (**7d**).* Dark red solid (0.25 g, 52%), mp 250–252 °C (ethanol). ^1H NMR (DMSO-d_6, 300 MHz) δ 2.62 (s, 3H, CH_3), 2.76 (s, 3H, CH_3), 7.39–8.20 (m, 14H, ArH); IR (KBr) ν_{max} 1617, 1523, 1450 cm^{-1}. MS *m*/*z* (%) 479 (M^++1, 1), 478 (M^+, 2), 476 (12), 325 (22), 272 (10), 111 (12), 77 (100). Anal. Calcd for $C_{27}H_{20}ClN_7$ (477.96): C, 67.85; H, 4.22; N, 20.51. Found: C, 67.71; H, 4.18; N, 20.35.

*4.5.5. 2,6-Dimethyl-3-[3-nitrophenylazo]-8,9-diphenyl-imidazo[1,2-b] pyrazolo[4,3-d]pyridazine (**7e**).* Dark pink solid (0.24 g, 49%), mp >300 °C (ethanol). ^1H NMR (DMSO-d_6, 300 MHz) δ 1.71 (s, 3H, CH_3), 2.49 (s, 3H, CH_3), 7.40–7.62 (m, 14H, ArH); IR (KBr) ν_{max} 1597, 1495 cm^{-1}. MS *m*/*z* (%) 489 (M^++1, 33), 488 (M^+, 91), 410 (20), 414 (18), 338 (24), 270 (38), 122 (12), 104 (10), 92 (13), 77 (100). Anal. Calcd for $C_{27}H_{20}N_8O_2$ (488.55): C, 66.39; H, 4.13; N, 22.94. Found: C, 66.21; H, 4.02; N, 22.56%.

*4.5.6. 2,6-Dimethyl-3-[4-nitrophenylazo]-8,9-diphenyl-imidazo[1,2-b] pyrazolo[4,3-d]pyridazine (**7f**).* Pink solid (0.27 g, 56%), mp 120–122 °C (dioxan). ^1H NMR (DMSO-d_6, 300 MHz) δ 2.32 (s, 3H, CH_3), 2.51 (s, 3H, CH_3), 7.14 (d, *J*=8 Hz, 2H, ArH), 7.22 (d, *J*=8 Hz, 2H, ArH), 7.45–7.88 (m, 10H, ArH); IR (KBr) ν_{max} 1605, 1525, 1475 cm^{-1}. MS *m*/*z* (%) 488 (M^+, 34), 487 (96), 486 (100), 444 (59), 368 (38), 367 (42), 341 (24), 338 (30), 106 (32), 91 (40), 77 (27). Anal. Calcd for $C_{27}H_{20}N_8O_2$ (488.51): C, 66.39; H, 4.13; N, 22.94. Found: C, 66.11; H, 4.58; N, 22.56%.

*4.5.7. 2,6-Dimethyl-3-[4-acetylphenylazo]-8,9-diphenyl-imidazo[1,2-b] pyrazolo[4,3-d]pyridazine (**7g**).* Brown solid (0.28 g, 57%), mp >300 °C (dioxan/ethanol). ^1H NMR (DMSO-d_6, 300 MHz) δ 2.32 (s, 3H, CH_3), 2.55 (s, 3H, CH_3), 2.61 (s, 3H, CH_3), 7.23–8.06 (m, 14H, ArH); IR (KBr) ν_{max} 1682, 1594, 1484 cm^{-1}. MS *m*/*z* (%) 486 (M^++1, 86), 485 (M^+, 100), 255 (66), 105 (4), 76 (4). Anal. Calcd for $C_{29}H_{23}N_7O$ (485.55): C, 71.74; H, 4.77; N, 20.19. Found: C, 71.52; H, 4.41; N, 19.76%.

References and notes

1. Shawali, A. S.; Parkanyi, C. *J. Heterocycl. Chem.* **1980**, *17*, 833–854.
2. Shawali, A. S. *Heterocycles* **1983**, *20*, 2239–2285.
3. Shawali, A. S. *Chem. Rev.* **1993**, *93*, 2731–2777.
4. Shawali, A. S.; Abdallah, M. A. *Adv. Heterocycl. Chem.* **1995**, *63*, 277–338.
5. Shawali, A. S.; Elsheikh, S. M. *J. Heterocycl. Chem.* **2001**, *38*, 541–559.

6. Shawali, A. S.; Mosselhi, M. A. N. *J. Sulfur Chem.* **2005**, *26*, 267–303.
7. Shawali, A. S.; Edrees, M. M. *ARKIVOC* **2006**, *IX*, 292–365.
8. Shawali, A. S.; Sherif, S. M. *Curr. Org. Chem.* **2007**, *11*, 773–799.
9. Shawali, A. S.; Farghaly, T. A. *Arkivoc* **2008**, *i*, 18–64.
10. Shawali, A. S.; Samy, N. A. *The open Bioactive Compd. J.* **2009**, *2*, 8–16.
11. Shawali, A. S.; Mosselhi, M. A. N. *J. Heterocycl. Chem.* **2003**, *40*, 725–746.
12. Shawali, A. S.; Abdel-kader, M. H.; Altalbawy, F. A. *Tetrahedron* **2002**, *58*, 2875–2880.
13. Sener, I.; Karci, F.; Ertan, N.; Kilic, E. *Dyes Pigments* **2006**, *70*, 143–148.
14. Uscumlic, G. S.; Mijin, D. Z.; Valentic, N. V.; vajs, V. V.; Susic, B. M. *Chem. Phys. Lett.* **2004**, *397*, 148–153.
15. Shawali, A. S.; Mosselhi, M. A. N.; Farghaly, T. A. *J. Chem. Res.* **2007**, 479–483.
16. Hassaneen, H. M.; Shawali, A. S.; Elwan, N. M.; Abounada, N. M. *Sulfur Lett.* **1992**, *13*, 273–285.
17. Farag, A. M.; Algarib, M. S. *Org. Prep. Proced. Int.* **1988**, *20*, 521–526.
18. Dawood, K. M.; Ragab, E. A.; Farag, A. M. *J. Chem. Res., Synop.* **2003**, 685–686; *J. Chem. Res., Miniprint* **2003**, 1151–1160.
19. Dawood, K. M.; Farag, A. M.; Abdel-Aziz, H. A. *J. Chin. Chem. Soc.* **2006**, *53*, 873–880.
20. Shawali, A. S.; Farghaly, T. A. *Tetrahedron* **2009**, *65*, 644–647.
21. Shawali, A. S.; Khattab, S. A.; Farag, A. M. *J. Chem. Eng. Data* **1977**, *22*, 104–110.
22. Shawali, A. S.; Farghaly, T. A.; Edrees, M. M. *Intern. Pure Appl. Chem.* **2006**, *1*, 531–537.
23. All crystallographic data have been deposited at the Cambridge Crystallographic Data Centre as supplementary publication no. CCDC 750071. Copies of the data can be obtained free of charge on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK