Chem. Pap. (2018) 72:683–690
https://doi.org/10.1007/s11696-017-0319-0

ORIGINAL PAPER

2*H*-Pyrano[3,2-*c*]quinolin-2-ones: their convenient synthesis and selected reactions

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Received: 19 August 2017 / Accepted: 9 October 2017 / Published online: 20 October 2017

Abstract Despite the structure attractiveness of 2*H*-pyrano[3,2-*c*]quinolin-2-ones **3** their synthesis is not sufficiently developed. Only 35 pyranoquinolinones **3** are registered in the SciFinder database. Unavailability of **3** limits their chemistry exploitation, physical and biological studies. We have developed a convenient and general methodology for the synthesis of **3**. Sixteen novel 2*H*-pyrano[3,2-*c*]quinolin-2-ones **3** were prepared by a cyclocondensation of easily available 4-oxo-1,4-dihydroquinoline-3-carbaldehydes **1** with monosubstituted acetic acids **2** (-aryl, -arylthio and -heteroaryl). To support chemistry exploitation of pyranoquinolinones **3**, oxoquinolinylphenylacrylic acids **4** were obtained by hydrolysis of **3** with NaOH (92–98%). A simple oxidation of **3** by MCPBA was performed to provide oxopyranoquinoline *N*-oxide **5** (71%). Convenient rearrangement of **5** in refluxing Ac_2O curried out 2*H*-pyrano[3,2-*c*]quinoline-2,5(6*H*)-dione **6** in 87% yield. Moreover, some of the prepared pyranoquinolinones **3** possess intensive blue fluorescence properties. Here we described the simple and general synthesis that allows availability of 2*H*-pyrano[3,2-*c*]quinolin-2-ones **3**. Some transformations of **3** to the novel heterocyclic compounds **4**–**6** were performed as well in good yields (71–98%). The synthesis of **6** from **3** was not yet described. The developed methodology for the synthesis of **3**–**6** can stimulate their further physical and pharmacological studies.

The authors Matúš Čakurda and Margita Lácová also contributed to writing this paper.

Electronic supplementary material The online version of this article (doi:10.1007/s11696-017-0319-0) contains supplementary material, which is available to authorized users.

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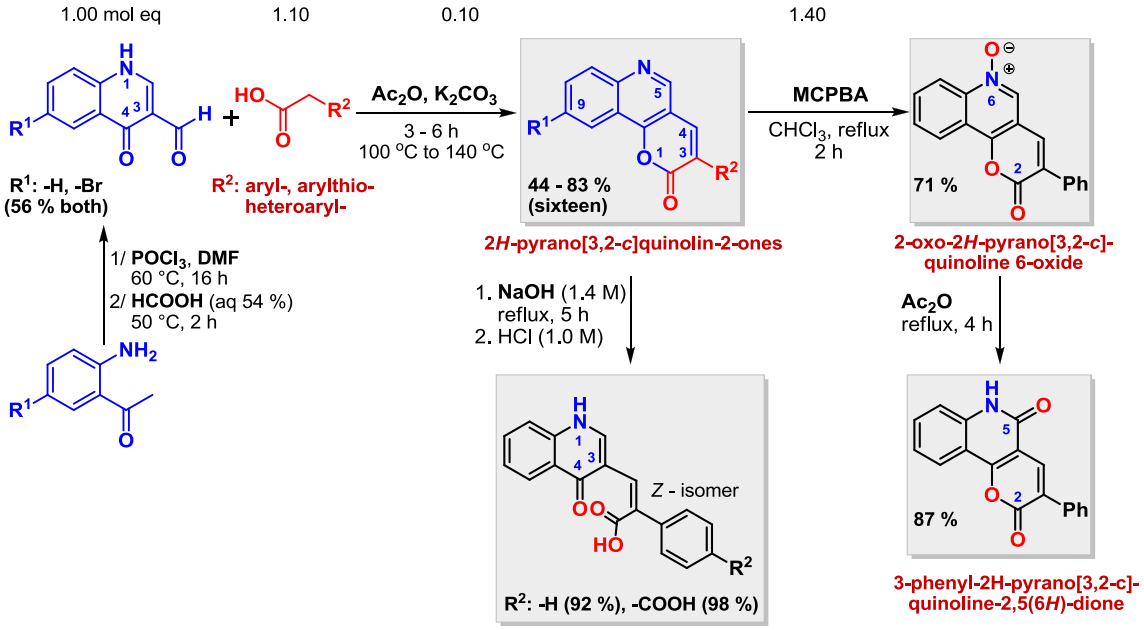
Graphical Abstract



Keywords 2*H*-Pyrano[3,2-*c*]quinolin-2-one · (*Z*)-3-(4-Oxo-1,4-dihydroquinolin-3-yl)-2-phenylacrylic acid · 2-Oxo-2*H*-pyrano[3,2-*c*]quinoline 6-oxide · Quinoline *N*-oxide · 2*H*-Pyrano[3,2-*c*]-quinoline-2,5(6*H*)-dione · Cyclocondensation · Fluorescence

Introduction

Synthesis and properties of 2*H*-pyrano[3,2-*c*]quinolin-2-ones **3** (Fig. 1) are described in the literature very insufficiently. Therefore, exploitations of **3** in life and material sciences are very limited. The scientific database (The SciFinder 2017) has registered only 35 derivatives of **3**, nineteen of them were prepared from 4-hydroxyquinolines in 66% yield (Anukumari et al. 2015), at 180–205 °C in 72–90% yields (Mohtat et al. 2013), at 180–230 °C within 2.5–4 days in 10–66% yields. Compounds **3** were also synthesized from 4-hydroxyquinoline-3-carbaldehyde at 60–140 °C within 2–11 days in 7–8% yields (Galariniotou et al. 2007) or at 110 °C within 16 h by Et_3N in Ac_2O (Chugger and Trivedi 1972). Other derivatives of **3** were prepared from 2,3-dihydroquinolin-4(1*H*)-one in 72% yield (Peruncheralathan et al. 2004), from 3-acetylquinolin-4(3*H*)-one in 70% yield (Ghorab et al. 2001), from quinolin-4(1*H*)-ones or quinoline in 43% yield (Nesterova et al. 1995, 1993). Some of compounds **3** were prepared from substituted 4-hydroxyquinoline in 79% (Soliman and Said 1991), by hydrolysis of substituted 2*H*-pyrano[3,2-*c*]quinolin-2-ones (Thakore and Trivedi 1980) or from derivatives of 4-hydroxyquinoline and 4-hydroxyquinoline-3-carbaldehyde in 88 and 99% yield, resp (Narasimhan and Bhagwat 1979). Even though 4-hydroxyquinoline (quinolin-4-ol) and quinolin-4(1*H*)-one are tautomers, both structures (used separately) can be found in the literature as a starting material. To perform good quality literature searches both tautomers should be considered.

Low availability of 2*H*-pyrano[3,2-*c*]quinolin-2-ones **3** could be a reason of their only few biological studies. Four compounds of **3** were studied in antibacterial/fungicide (Ghorab et al. 2001) or neuromuscular and psychotropic

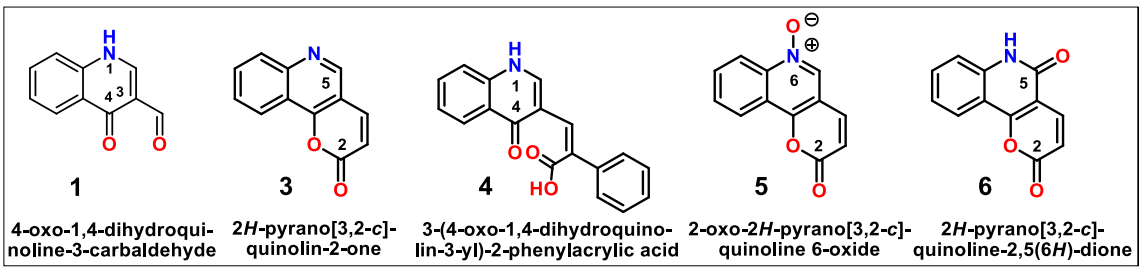
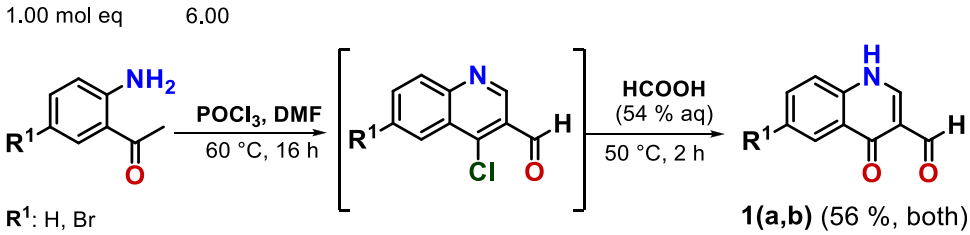


Fig. 1 The structures and names of heterocyclic compounds **1**, **3**–**6**

Scheme 1 The synthesis of 4-oxo-1,4-dihydroquinoline-3-carbaldehydes **1(a,b)**



assays (Nesterova et al. 1995). As we show in this paper also other interesting heterocyclic compounds **4**–**6** (Fig. 1) can be easily prepared from pyranoquinolinones **3**.

According to the SciFinder database, 3-(4-oxo-1,4-dihydroquinolin-3-yl)-2-phenylacrylic acids **4** and *N*-oxides possessing 2-oxo-2*H*-pyrano[3,2-*c*]quinolines **5** are completely unknown. There are 79 registered 2*H*-pyrano[3,2-*c*]quinoline-2,5(6*H*)-diones **6** with 28 preparations, whereby none of them starts from **3** as we performed here. Until now, only eighteen derivatives of **6** were studied in anti-infective, antitumor and hormone antagonist assays (The SciFinder database 2017). Therefore, we decided to develop general synthesis of **3** to make this kind of rare heterocyclic compounds accessible for further biological and material studies. Additionally we aimed to explore chemistry potential of **3** via selected transformations to prepare different heterocyclic compounds **4**–**6**.

Experimental

Materials

Melting points were measured using Kofler apparatus or Barnstead Electrothermal IA9200 and are uncorrected. ^{1}H- and ^{13}C-NMR spectra were recorded on Varian Gemini (300/600 MHz and 75/150 MHz, respectively), chemical shifts are given in parts per million (ppm), tetramethylsilane was used as an internal standard and DMSO-*d6* as the solvent, unless otherwise specified. The abbreviation dm in the ^{1}H NMR spectra means doublet of multiplet. It describes more complex couplings observed at some of aromatic hydrogens. IR spectra were acquired on FT-IR-ATR REACT IR 1000 (ASI Applied Systems) with diamond probe and MTS detector. Mass spectra were performed on LC–MS (Agilent Technologies 1200 Series equipped with Mass spectrometer Agilent Technologies 6100 Quadrupole LC–MS). The course of the reactions was followed by TLC analysis (Merck Silica gel 60 F254). UV lamp (254 nm) and iodine vapours were used for the visualization of TLC spots. Starting chemicals were purchased from Sigma-Aldrich, Fluorochem, Alfa Aesar or Acros vendors. Used abbreviations EA, FLC and TLC mean ethyl acetate, flash liquid chromatography and thin layer chromatography, resp.

General procedure A—the synthesis of quinolinecarbaldehydes 1(a,b)

A formylation mixture was prepared from 41.2 mL (444.4 mmol, 6.00 mol eq) of $POCl_3$ that was added dropwise to 90.0 mL of DMF (abs) at 0 °C. Resulted solution was stirred for 15 min under Ar at rt. Then 9.0 mL (74.0 mmol, 1.00 mol eq) of 1-(2-aminophenyl)ethanone was added dropwise to the stirred formylation mixture within 30 min and the mixture heated to 60 °C for 16 h (instead of 4 h, described previously in the literature) (Seixas et al. 2011). Then, the mixture was cooled to rt by adding 400 g of crashed ice in 200 mL H_2O and the reaction neutralized to pH 7 by solid $NaHCO_3$. Precipitated yellow product was filtered off, dissolved in $CHCl_3$, extracted with water. A separated organic layer was dried over Na_2SO_4, filtered, concentrated by RVO and HV. Crystallization from EA with charcoal bleaching provided 8.50 g (44.4 mmol, 60%) of 4-chloroquinoline-3-carbaldehyde in form of a white solid material. A suspension of the crude 4-chloroquinoline-3-carbaldehyde in 80 mL of HCOOH (54% aqueous) was hydrolyzed at 50 °C within 2 h. The mixture was cooled down and left in refrigerator overnight. The formed solid product was filtered off, washed with H_2O, Et_2O and dried under HV. The 1,4-dihydro-4-oxoquinoline-3-carbaldehyde **(1a)** was obtained as a white solid 7.15 g (41.23 mmol, 93 or 56% overall yield) and used for further synthetic step (Scheme 1).

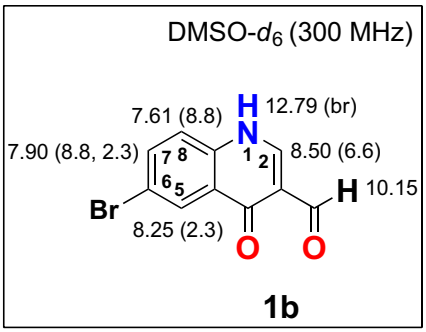
4-Oxo-1,4-dihydroquinoline-3-carbaldehyde (1a)

The compound **1a** was prepared in 56% overall yield following the General procedure A. The quinolinecarbaldehyde **1a** is described previously in the literature (Seixas et al. 2011). For physico-chemical characteristics of **1a** see the Supporting Information.

6-Bromo-4-oxo-1,4-dihydroquinoline-3-carbaldehyde (1b)

The compound **1b** was prepared according to the General procedure A, starting from 1.58 g (7.4 mmol, 1.00 mol eq) of 1-(2-amino-5-bromophenyl)ethanone. The crude product 1.04 g (4.13 mmol, 90%) of **1b** was obtained as a light brown solid material. The compound **1b** is not described previously in the literature.

M.p.: 326.0–326.2 °C (dec) [HCOOH, 54% aq].



^{1}H-NMR (300 MHz, DMSO-d_6) δ 12.79 (br d, 1H, J (2, NH) = 6.6 Hz included, –NH–), 10.15 (s, 1H, –CHO), 8.50 (d, 1H, J (2, NH) = 6.6 Hz, H–C(2)), 8.25 (d, 1H, Hz, J (5, 7) = 2.3 Hz, H–C(5)), 7.90 (dd, 1H, J (7, 8) = 8.8 Hz, J (5, 7) = 2.3 Hz, H–C(7)), 7.61 (d, 1H, J (7, 8) = 8.8 Hz, H–C(8)).

^{13}C-NMR (75 MHz, DMSO-d_6) δ 188.5 (–CHO), 174.9 (C(4)), 143.6 (C(2)), 138.4 (C(7)), 135.8 (C(4b)), 129.2 (C(5)), 127.4 (C(4a)), 121.9 (C(3)), 118.2 (C(6)), 116.5 (C(8)).

IR (neat, ν in cm^{-1}): 3199 (w), 3155 (m), 3064 (s), 3027 (s), 3027 (s), 2986 (s), 2944 (s), 2905 (s), 2867 (s), 1701 (m), 1679 (s, C=O), 1620 (s, –CHO), 1608 (s), 1573 (s), 1551 (m), 1519 (s), 1459 (m), 1411 (m), 1375 (w), 1345 (m), 1296 (m), 1264 (w), 1198 (w), 1166 (w), 1131 (w), 1071 (w), 989 (w), 962 (w), 868 (w), 825 (m), 786 (m), 747 (w), 695 (w), 660 (w), 624 (w).

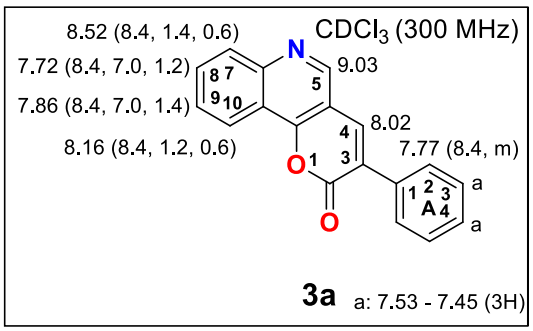
Anal. calcd for $C_{10}H_6BrNO_2$ (252.06): C, 47.65; H, 2.40; N, 5.56. Found: C, 47.92; H, 2.44; N, 5.87.

General procedure B—the synthesis of 2*H*-pyrano[3,2-*c*]quinolin-2-ones 3(a-h, j-q)

A mixture of 100.0 mg (0.58 mmol, 1.00 mol eq) 1,4-dihydro-4-oxoquinoline-3-carbaldehyde **1a** together with 87.0 mg (0.639 mmol, 1.10 mol eq) of phenylacetic acid (**2a**) and 8.00 mg (0.639 mmol, 0.10 mol eq) of K_2CO_3 (abs) was stirred in 3 mL of freshly distilled Ac_2O at 130 °C for 4 h. After cooling the reaction mixture to rt, the solid product **3a** was filtered off, washed with H_2O (2 × 5 mL), Et_2O (1 × 5 mL) and dried under *vacuum* to yield 129 mg (0.46 mmol, 80%) of **3a** (Scheme 2). Here we are showing physico-chemical characteristics for the compound **3a**. The characteristics for all sixteen novel compounds **3** together with their spectral figures are published in the Supporting Information.

3-Phenyl-2*H*-pyrano[3,2-*c*]quinolin-2-one (**3a**) was prepared following the General procedure B (130 °C/4 h) yielding a pale yellow crude product 127 mg (0.46 mmol, 80%). The compound **3a** is not described previously in the literature.

M.p.: 233.8–234.9 °C [Ac_2O].



^{1}H-NMR (300 MHz, $CDCl_3$) δ 9.03 (s, 1H, H–C(5)), 8.52 (ddd, 1H, J (7, 8) = 8.4 Hz, J (7, 9) = 1.4 Hz, J (7, 10) = 0.6 Hz, H–C(7)), 8.16 (ddd, 1H, J (9, 10) = 8.4 Hz, J (8, 10) = 1.2 Hz, J (7, 10) = 0.6 Hz, H–C(10)), 8.02 (s, 1H, H–C(4)), 7.86 (ddd, 1H, J (9, 10) = 8.4 Hz, J (8, 9) = 7.0 Hz, J (7, 9) = 1.4 Hz, H–C(9)), 7.77 (dm, 2H, among others J (2_A, 3_A) = 8.4 Hz, H–C_A(2)), 7.72 (ddd, 1H, J (7, 8) = 8.4 Hz, J (8, 9) = 7.0 Hz, J (8, 10) = 1.2 Hz, H–C(8)), 7.53–7.45 (m, 3H, H–C_A(3–4)).

^{13}C-NMR (75 MHz, $CDCl_3$) δ 159.4 (C(2)=O), 155.9 (C(4b)), 149.0 and 148.9 (C(5) and C_A(4)), 137.6 (C(4)), 134.1 (C_A(1)), 131.6 (C(3)), 129.5, 129.3 and 128.7, 2 × 128.6 and 2 × 128.4 (C_A(2,3) from terminal phenyl, ring A), 127.7, 122.0 (C(10)), 117.6 (C(6b)), 111.4 (C(4a)).

IR (neat, ν in cm^{-1}): 3047 (m), 1718 (s, C=O), 1682 (m), 1628 (m), 1598 (w), 1564 (w), 1501 (m), 1445 (m), 1414 (w), 1394 (m), 1289 (w), 1088 (m), 1024 (m), 1010 (m), 958 (m), 950 (m), 907 (m), 897 (m), 789 (m), 762 (m), 742 (m), 691 (m), 681 (m), 663 (w), 626 (w).

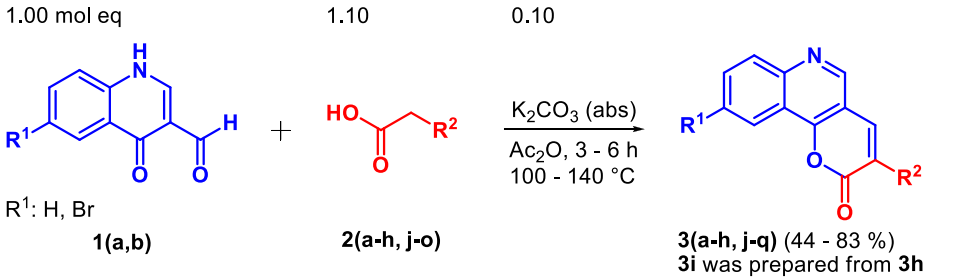
ESI MS: m/z 274.1 $[M + H]^+$.

Anal. calcd for $C_{18}H_{11}NO_2$ (273.29): C, 79.11; H, 4.06; N, 5.13. Found: C, 79.25; H, 4.11; N, 5.07.

General procedure C—the synthesis of (*Z*)-3-(4-oxo-1,4-dihydroquinolin-3-yl)-2-phenylacrylic acids 4(a,b)

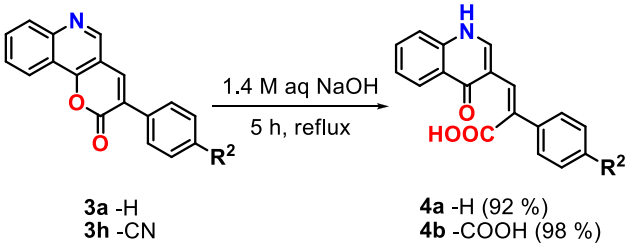
A suspension of 100 mg (0.366 mmol, 1.00 mol eq) **3a** in 5 mL of 1.4 M aq NaOH solution was refluxed within 5 h. After cooling to rt the mixture was extracted with $CHCl_3$ (3 × 3 mL), water layer separated and treated by 1.0 M aq solution of HCl to pH 4. A precipitated light yellow solid material was filtered off, washed with H_2O, Et_2O and dried by *vacuum* to afford 98.0 mg (0.336 mmol, 92%) of **4a**. By the same conditions **4b** was prepared in 98% yield (Scheme 3). Physico-chemical characteristics for the compound **4a** are stated below. The compound **4b** is characterized in the Supporting Information.

Scheme 2 The synthesis of the pyranoquinolinones **3(a-h, j-q)**



3(a-o, x) (R^1: H): **a** (R^2: Ph-, 80 %); **b** (*p*-MeOPh-, 73 %); **c** (*m*-MeOPh-, 59 %); **d** (*p*-FPh-, 72 %); **e** (*m*-ClPh-, 65 %); **f** (*p*-NO_2Ph-, 83 %); **g** (*m*-NO_2Ph-, 82 %); **h** (*p*-NCPh-, 60 %); **i** (*p*-HOOCPh-, prepared by hydrolysis of **3h** in 97 %); **j** (*p*-N_3Ph-, 44 %); **k** (PhS-, 47 %); **l** (*p*-ClPhS-, 61 %); **m** (thiophene-2-yl, 50 %); **n** (thiophene-3-yl, 78 %); **o** (1-acetyl-1*H*-indol-3-yl, 64 %); **x** (H-, not observed)

3(p-q) (R^1: Br): **p** (R^2: Ph-, 53 %); **q** (*p*-MeOPh-, 47 %)



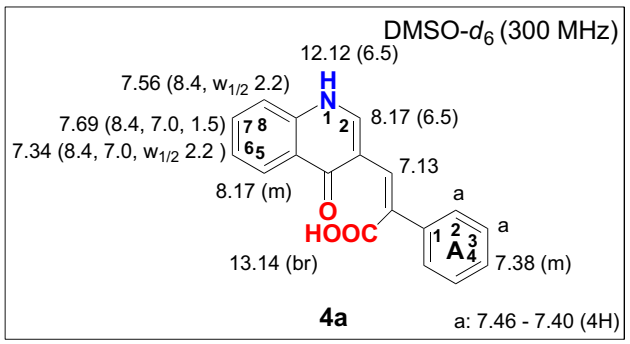
Scheme 3 The hydrolysis of pyranoquinolinones **3** to *Z-regioisomers* of quinolinylphenylacrylic acids **4**

(Z)-3-(4-oxo-1,4-dihydroquinolin-3-yl)-2-phenylacrylic acid (4a)

The compound **4a** was prepared according to the General procedure C in 92% yield (Scheme 3).

The compound **4a** is not described previously in the literature.

M.p.: > 244 °C (dec) [H_3O^+].



^{1}H-NMR (300 MHz, DMSO-d_6) δ 13.14 (br s, 1H, –COOH), 12.12 (d, 1H, *J* (NH, 2) = 6.5 Hz, –NH–), 8.17 (d, 1H, *J* (NH, 2) = 6.5 Hz, H–C(2)), 8.17 (m, 1H, H–C(5)), 7.69 (dd, 1H, *J* (7, 8) = 8.4 Hz, *J* (6, 7) = 7.0 Hz, *J* (5, 7) = 1.5 Hz, H–C(7)), 7.56 (dm, 1H, *J* (7, 8) = 8.4 Hz, $w_{1/2}$ = 2.2 Hz, H–C(8)), 7.46–7.40 (m, 4H, 2 × H–C(2_A) and 2 × H–C(3_A)), 7.38 (m H–C(4_A)), 7.34 (ddm, 1H, *J* (5, 6) = 8.4 Hz, *J* (6, 7) = 7.0 Hz, $w_{1/2}$ = 2.2 Hz, H–C(6)), 7.13 (s, 1H, H–C(C(3))=C).

^{13}C-NMR (75 MHz, DMSO-d_6): δ 175.5 (C(4)), 171.0 (–COOH), 139.5, 138.3, 138.0, 133.4, 132.4, 129.0, 128.1, 126.6, 125.9, 125.4, 124.6, 124.3, 118.9, 116.5.

IR (neat) ν/cm^{-1}: 3816 (w), 3751 (w), 3674 (w), 3215 (w), 3046 (w), 3004 (w), 2356 (m), 2335 (w), 2191 (w), 2145 (w), 2023 (w), 2006 (w), 1995 (w), 1820 (w), 1676 (s) (C=O), 1629 (s), 1579 (m), 1549 (s), 1492 (s), 1474 (s), 1347 (m), 1307 (m), 1288 (m), 1226 (m), 1203 (s), 1153 (m), 1112 (m), 1003 (m), 942 (m), 898 (m), 859 (m), 820 (m), 777 (s), 753 (s), 693 (s), 659 (m), 625 (m).

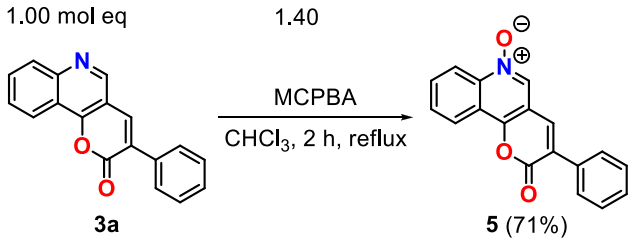
ESI MS: *m/z* 290.0 $[M - H]^-$.

Anal. calcd for $C_{18}H_{13}NO_3$ (291.30): C, 74.22; H, 4.50; N, 4.81. Found: C, 74.55; H, 4.68; N, 5.12.

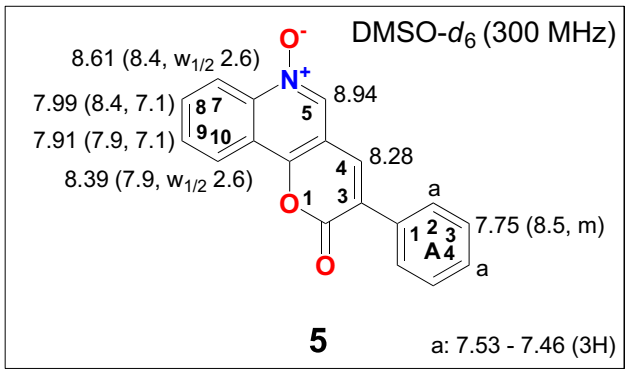
2-Oxo-3-phenyl-2H-pyrano[3,2-c]quinolone 6-oxide (5)

To a solution of 100 mg (0.366 mmol, 1.00 mol eq) **3a** in 5 mL $CHCl_3$, 109 mg (0.476 mmol, 1.40 mol eq, ≥ 77% purity) of MCPBA was added and the mixture stirred at reflux for 2 h. Then the reaction mixture was diluted with 15 mL of $CHCl_3$ and washed with sat aq solution of $NaHCO_3$ (2 × 10 mL). The organic layer was separated, dried over Na_2SO_4, filtered and the solvent removed by *vacuum*. The crude product was purified by FLC [SiO_2, from $CHCl_3$ to $CHCl_3$/MeOH (98/2)] to yield 75.0 mg (0.26 mmol, 71%) of 2-oxo-3-phenyl-2*H*-pyrano[3,2-*c*]quinolone 6-oxide **(5)** as a yellow solid material (Scheme 4). The compound **5** is not described previously in the literature.

M.p.: > 246 °C (dec) [MeOH].



Scheme 4 The MCPBA oxidation of the pyranoquinolinone **3a** to the pyranoquinoline *N-oxide* **5**



^{1}H-NMR (300 MHz, DMSO-d_6): δ 8.94 (s, 1H, H–C(5)), 8.61 (dm, 1H, J (7, 8) = 8.4 Hz, $w_{1/2}$ = 2.6 Hz, H–C(7)), 8.39 (dm, 1H, J (9, 10) = 7.9 Hz, $w_{1/2}$ = 2.6 Hz, H–C(10)), 8.28 (s, 1H, H–C(4)), 7.99 (dd, 1H, J (7, 8) = 8.4 Hz, J (8, 9) = 7.1 Hz, H–C(8)), 7.91 (dd, 1H, J (9, 10) = 7.9 Hz, J (8, 9) = 7.1 Hz, H–C(8)), 7.75 (dm, 2H, among others J (2_A, 3_A) = 8.5 Hz, 2 × H–C_A(3)), 7.53–7.46 (m, 3H, among others J (2_A, 3_A) = 8.5 Hz, 2 × H–C_A(2), H–C_A(4)).

^{13}C-NMR (75 MHz, $CDCl_3$): δ 159.1 (C(2)(=O)), 146.6 (C(4b)), 141.5 (C(6a)), 137.6 C(5)), 134.5 (C(4)), 133.2, 132.7, 130.5, 129.6, 129.0, 128.91, 128.90, 122.9, 120.3, 119.4, 112.9 (C(7)).

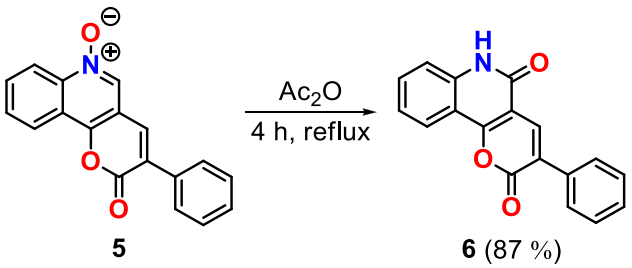
IR (neat) ν/cm^{-1}: 3039 (w), 2917 (w), 1719 (s, C=O), 1615 (w), 1579 (w), 1515 (w), 1468 (w), 1445 (m), 1398 (s), 1334 (m), 1268 (w), 1219 (s, N–O), 1189 (m), 1161 (m), 1146 (m), 1079 (m), 1041 (s), 1013 (m), 954 (w), 890 (s), 782 (s), 769 (s), 721 (s), 709 (s), 692 (s), 674 (s), 656 (s).

ESI MS: m/z 290.0 $[M + H]^+$.

Anal. calcd for $C_{18}H_{11}NO_3$ (289.28): C, 74.73; H, 3.83; N, 4.84 Found: C, 74.97; H, 4.12; N, 5.06.

3-Phenyl-2H-pyrano[3,2-c]quinoline-2,5(6H)-dione (6)

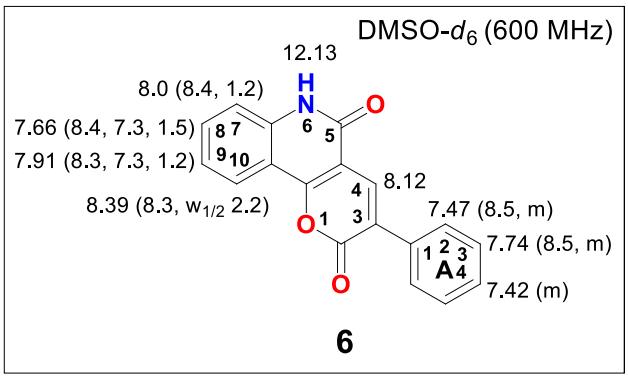
A solution of 100 mg (0.380 mmol, 1.00 mol eq) **5** was dissolved in 8 mL of Ac_2O and refluxed within 4 h. After



Scheme 5 The convenient rearrangement of the pyranoquinoline *N-oxide* **5** to the pyranoquinolinedione **6**

consumption of the starting material **5** (monitored by TLC) the mixture was cooled to rt and stirred for additional 1 h. A precipitated solid material was filtered off, washed with Ac_2O, Et_2O and dried by *vacuum* to afford 96.0 mg (0.332 mmol, 87%) of **6** as a light yellow solid material (Scheme 5). The compound **6** is registered in the SciFinder database under CAS (98986-64-2), but no characterization and no synthesis are available.

M.p.: > 390 °C (dec) [Ac_2O].



^{1}H-NMR (600 MHz, DMSO-d_6): δ 12.13 (s, 1H, –NH–), 8.12 (s, 1H, H–C(4)), 8.39 (dm, 1H, J (9, 10) = 8.4 Hz, $w_{1/2}$ = 2.2 Hz, H–C(10)), 8.0 (dd, 1H, J (7, 8) = 8.4 Hz, J (7, 9) = 1.2 Hz, H–C(7)), 7.91 (ddd, 1H, J (9, 10) = 8.3 Hz, J (8, 9) = 7.3 Hz, J (7, 9) = 1.2 Hz, H–C(9)), 7.74 (dm, 2H, J (2_A, 3_A) = 8,5 Hz, 2 × H–C_A(3)), 7.66 (ddd, 1H, J (7, 8) = 8.4 Hz, J (8, 9) = 7.3 Hz, J (8, 10) = 1.5 Hz, H–C(8)), 7.47 (dm, 2H, J (2_A, 3_A) = 8.5 Hz, 2 × H–C_A(2)), 7.42 (m, 1H, H–C_A(4)).

^{13}C-NMR (150 MHz, DMSO-d_6): δ 159.7, 159.4, 158.6, 139.3, 137.0, 134.6, 133.4, 129.2, 128.9, 128.7, 126.0, 123.4, 122.9, 116.5, 112.2, 109.0.

IR (neat) ν/cm^{-1}: 3329 (w) (–NH–), 3017 (w), 2964 (w), 2816 (m), 2344 (w), 2113 (w), 1900 (w), 1730 (s) (C=O), 1660 (s) (C=O), 1558 (s), 1502 (s), 1440 (s), 1408 (s), 1294 (m), 1258 (m), 1080 (m), 1010 (m), 890 (s), 760 (s), 750 (s), 690 (s).

Anal. calcd for $C_{18}H_{11}NO_3$ (289.28): C, 74.73; H, 3.83; N, 4.84 Found: C, 75.01; H, 4.19; N, 5.12.

Results and discussion

A simple synthesis of 1,4-dihydro-4-oxoquinoline-3-carbaldehydes **1(a,b)** was performed. The synthesis of a brominated analogue **1b** is not described previously in the literature (Scheme 1).

The sixteen novel pyrano[3,2-*c*]quinolin-2-ones **3(a–h, j–q)** were prepared by heating of appropriate quinolinecarbaldehyde **1** with an appropriate acetic acid derivative **2** in Ac_2O by catalysis of K_2CO_3 (abs) at 100–140 °C within 3–6 h. The pyranoquinolinones **3** were easily isolated from their mixtures as they precipitated within the reaction in a good yield and purity (Scheme 2). 4-(2-Oxo-2*H*-pyrano[3,2-*c*]quinolin-3-yl)benzoic acid (**3i**) was prepared in 97% yield by hydrolysis of **3h** in refluxing 1.4 M aq solution of NaOH within 5 h.

In the all performed cyclocondensations (Scheme 2) Ac_2O was used as a reactant and as a solvent. In each case the free AcOH was formed as a side product and could compete with **2** in a reaction with quinolinecarbaldehyde **1** to give an unsubstituted side product **3x** (R^1=R^2: H). However, the compound **3x** was never observed in any of our products **3(a–h, j–q)**. Moreover, we performed a reaction between **1a** and acetic acid instead of **2** by the same reaction conditions. In this case no product **3x** was formed even by heating of the mixture at 140 °C overnight.

To support the chemistry exploitation of 2*H*-pyrano[3,2-*c*]quinolin-2-ones **3**, hydrolysis of two derivatives **3(a,h)** was performed to yield oxoquinolinylphenylacrylic acids **4(a,b)** in excellent 92–98% yields (Scheme 3). *Z*-geometry of both products **4(a,b)** was proved by NOESY-1D NMR experiments that confirmed an interaction between H–C(3) from an acrylic acid with both hydrogens: H–C(2) from a quinolin-4(1*H*)-one part and an *ortho* hydrogen from a phenyl substituent joint to the acrylic acid.

An oxidation of 2*H*-pyrano[3,2-*c*]quinolin-2-one **3a** was performed by MCPBA in refluxing $CHCl_3$ within 2 h. An *N*-oxide **5** was prepared in 71% yield after FLC purification (Scheme 4).

The novel synthesis of pyranoquinolinedione **6** was performed in 87% yield by a simple rearrangement of the oxopyranoquinoline *N*-oxide **5** in refluxing Ac_2O (Scheme 5).

The novel heterocyclic compounds **4–6** were prepared from 2*H*-pyrano[3,2-*c*]quinolin-2-ones **3** in good yields confirming the convenient chemistry exploitation of **3**.

Additionally a small fluorescence study was performed with the selected pyranoquinolinones: **3a** (R^2: Ph–), **3b** (R^2: *p*-MeOPh–) and **3f** (R^2: *p*-O_2NPh–) in $CHCl_3$ and CH_3OH. The wavelengths (nm) for excitation and emission were determined: **3a** ($\lambda_{exc} = 340$, $\lambda_{Fmax} = 423$), **3b** ($\lambda_{exc} = 325$, $\lambda_{Fmax} = 449$) and **3f** ($\lambda_{exc} = 350$, $\lambda_{Fmax} = 434$). The highest fluorescent quantum yield was observed for unsubstituted compound **3a** ($\varphi F = 0.63$) compare to the other derivatives **3b** (< 0.01) and **3f** (0.04) in MeOH (for more details see the Supporting Information).

Conclusion

Here we described the convenient synthesis of 2*H*-pyrano[3,2-*c*]quinolin-2-ones **3** starting from easily available quinolinecarbaldehydes **1** and monosubstituted acetic acids **2** (-aryl, -arylthio and -heteroaryl). Sixteen novel compounds **3** were prepared by the above methodology to confirm its general exploitation. Some examples of chemistry transformations of **3** yielding the novel heterocyclic compounds **4–6** were performed in good yields (71–98%). The compounds **4–6** are not described previously in the literature and the synthesis of compounds **6** from **3** is novel as well. All together 24 compounds were prepared and well physico-chemical characterized in the Supporting Information. Additionally we observed that some of the pyranoquinolinones **3** possess intensive blue fluorescence properties. The presented synthesis of pyranoquinolinones **3** and their transformations to the compounds **4–6** can accelerate further physical and biological studies of these heterocyclic compounds.

Acknowledgements This research was supported by the Comenius University in Bratislava UK/416/2015, theBiomagi, Ltd., VEGA 1/0634/13 and ITMS 26240220007.

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