Quinazoline-containing Hydrazides of Dicarboxylic Acids and Products of Their Structural Modification: A Novel Class of Anti-inflammatory Agents

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Abstract

The synthesis of hydrazides formed by quinazolin-4(3H)-ylidenehydrazine and dicarboxylic acids, as well as their further modification are described in the present manuscript. It was shown that above-mentioned hydrazides may be obtained via acylation of initial quinazolin-4(3H)-ylidenehydrazine by corresponding acylhalides, cyclic anhydrides and imidazolides of dicarboxylic acids monoesters. Obtained hydrazides were converted into [1,2,4]triazolo[1,5-c]quinazolines that were used as initial compounds for chemical modification aimed to the introduction of amide fragment to the molecule. The IR, 1H NMR and chromato-mass spectral data of obtained compounds were studied and discussed. Obtained substances were studied for anti-inflammatory activity using carrageenan-induced paw inflammation model. Amides of ([1,2,4]triazolo[1,5-c]quinazoline-2-yl)alkyl carboxylic acids were detected as promising class of anti-inflammatory agents for further purposeful synthesis and profound study of anti-inflammatory activity.

Keywords: [1,2,4]triazolo[1,5-c]quinazolines, quinazolines; anti-inflammatory activity

1. Introduction

The search for new biologically active compounds and the further development of drugs based on them is one of the most important tasks of medicinal and organic chemistry. It should be noted that elaboration of the new biologically active agents is a multistep process and choice of the research strategy and objects of investigation are quite important stages. Hydrazides formed by quinazolin-4(3H)-ylidenehydrazine are one of the promising objects for studies aimed to the development of novel pharmacologically active substances. Such high potential of above-mentioned compounds caused by the possibility of chemical modification aimed to the introduction of diverse pharmacophore fragments.1–7 Moreover, cyclisation of above-mentioned hydrazides yielded substituted triazolo[c]quinazolines that show a wide range of biological activity including anticonvulsant, antitumor, hypoglycemic, antibacterial and other activities.8–21 Despite the numerous publications devoted to the chemistry and biology of hydrazides formed by quinazolin-4(3H)-ylidenehydrazine, some features of their formation, reactivity, physico-chemical and biological properties have been insufficiently studied. One of the promising directions of studies is the synthesis and further cyclization of hydrazides formed by quinazolin-4(3H)-ylidenehydrazine and dicarboxylic acids or their monoesters. These transformations would allow to combine heterocyclic fragments with quinazoline or [1,2,4]triazolo[1,5-c]quinazoline heterocyclic fragment, what is reasonable in scope of elaboration of novel anti-inflammatory agents.

Therefore, the aim of the present study is to develop procedures for the synthesis of hydrazides formed by quinazolin-4(3H)-ylidenehydrazine and derivatives of di-
carboxylic acids. Also the purpose was to study their cyclization, further modification of obtained tricyclic derivatives, as well as to study physicochemical properties and anti-inflammatory activity of obtained products.

2. Experimental Section

Melting points were determined in open capillary tubes in a «Stuart SMP30» apparatus and are uncorrected. The elemental analyses (C, H, N) were performed using the «ELEMENTAR vario EL cube» analyzer. IR spectra (4000–600 cm⁻¹) were recorded on a Bruker ALPHA FT-IR spectrometer using a module ATR eco ZnSe. ¹H NMR (400 MHz) were recorded on a Varian-Mercury (4000–6000 cm⁻¹) were recorded on a Bruker ALPHA FT-IR spectrometer using a module ATR eco ZnSe. ¹H NMR were performed using chromatography/mass spectrometric «Agilent 1100 Series» (Agilent, Palo Alto, CA, USA) equipped with diode-matrix and mass-selective detector «Agilent LC/MS SL» (atmospheric pressure chemical ionization – APCI). The purity of all obtained compounds was checked by ¹H NMR and LC-MS. Compounds 1a was synthesized according to the reported procedures.¹⁻³ Other starting materials and solvents were obtained from commercially available sources and were used without additional purification.

2.1. General Method for the Synthesis of 2-(4(3H)-Quinazolinylidene)hydrazides of Dicarboxylic Acids and Their Monoesters (2a–f)

Method A. 1.11 g (11 mmol) of triethylamine was added to the suspension of 1.6 g (10 mmol) of 2-hydroxyquinazoline (1a) in 10 mL of dioxane. The formed mixture was cooled to 0–5 °C and 11 mmol of ethyl 2-chloro-2-oxoacetate or ethyl 3-chloro-3-oxopropanoate was added under stirring. The formed mixture was stirred for 1.5 h at 0–5 °C, then poured in saturated solution of sodium acetate. The formed mixture was filtered off and dried. For additional purification compounds 2a and 2b may be crystallized from methanol.

Method B. 1.78 g (11 mmol) of N,N'-carbonyldimidazole (CDI) was added to the solution of corresponding monoethyl ester of dicarboxylic acid in 20 mL of anhydrous dioxane. The formed mixture was heated at 80 °C for 1 h (until the carbon dioxide was completely released). Then 1.6 g (10 mmol) of 4-hydrazinoquinazoline (1a) was added and stirred for 1.5–3 h. The formed mixture was cooled and poured into water and acidified to pH 5–6. The formed mixture was filtered off and dried. For additional purification compounds 2a and 2b may be crystallized from methanol.

Compounds 2a and 2b that were synthesized by methods A and B have identical physicochemical properties.

Method C. 11 mmol of corresponding anhydride of dicarboxylic acid under stirring was added to the suspension of 1.6 g (10 mmol) of 4-hydrazinoquinazoline (1a) in 10 mL of dioxane. Formed mixture was stirred at ambient temperature for 24 h or at 80 °C for 1–1.5 h. Then, reaction mixture was cooled, and the formed mixture was filtered off, washed by ethanol and dried. For additional purification obtained compounds may be crystallized from methanol.

Ethyl 2-oxo-2-(2-(quinazolin-4(3H)-ylidene)hydrazinyl)acetate (2a). Yield: 1.83 g (70%) (method A), 2.25 g (86%) (method B). Mp 199–202 °C; IR ν 3007 (νN=O), 1714 (ν CO), 1689 (ν CO2), 1616 (δ NH), 1546, 1444, 1110 (ν CO), 760, 688 cm⁻¹. ¹H NMR (400 MHz, DMSO-d₆) δ 1.36 (t, J = 7.1 Hz, 3H, -CH₃), 4.28 (q, J = 7.1 Hz, 2H, -CH₂-), 7.17 (d, J = 7.8 Hz, 1H, H-8), 7.26 (t, J = 7.9 Hz, 1H, H-6), 7.42 (t, J = 7.9 Hz, 1H, H-7), 7.91 (s, 1H, H-2), 8.02 (d, J = 7.8 Hz, 1H, H-5), 11.11 (br. s, 1H, -NH), 11.79 (br. s, 1H, -NH). LC-MS m/z = 261 [M+1]; Anal. Calcd. for C₆H₁₂N₂O₃: C, 55.38; H, 4.65; N, 21.53; Found: C, 55.46; H, 4.71; N, 21.58.

Ethyl 3-oxo-3-(2-(quinazolin-4(3H)-ylidene)hydrazinyl)propanoate (2b). Yield: 1.93 g (70%) (method A), 2.42 g (88.3%) (method B). Mp 165–167 °C; IR ν 3250 (νN=O), 1723 (ν CO), 1656 (ν CO2), 1519 (δ NH), 1435, 1309, 1158 (ν CO), 1023, 987, 759, 640 cm⁻¹. ¹H NMR (400 MHz, DMSO-d₆) δ 1.24 (t, J = 7.1 Hz, 3H, -CH₃(CH₂)₄), 3.46 (s, 2H, -CH₂-), 4.16 (q, J = 7.1 Hz, 2H, -CH₂(CH₂)₃), 7.17 (d, J = 7.8 Hz, 1H, H-8), 7.26 (t, J = 7.9 Hz, 1H, H-6), 7.42 (t, J = 7.9 Hz, 1H, H-5), 7.91 (s, 1H, -NH), 11.06 (br. s, 1H, -NH). LC-MS m/z = 275 [M+1]; Anal. Calcd. for C₆H₁₄N₂O₃: C, 56.93; H, 5.15; N, 20.43; Found: C, 57.02; H, 5.19; N, 20.48.

4-Oxo-4-(2-(quinazolin-4(3H)-ylidene)hydrazinyl)butanoic acid (2c). Yield: 2.43 g (93%) (method C). Mp 177–179 °C; IR ν 3270 (νOH), 3258 (νNH), 1703 (ν CO2), 1602 (ν CO), 1555 (δ NH), 1527, 1442, 1212, 929 (δ OH), 740, 687 cm⁻¹. ¹H NMR (400 MHz, DMSO-d₆) δ 2.91 (m, 2H, -CH₂CH₂), 3.58 (m, 2H, -CH₂CH₂), 7.10 (d, J = 7.7 Hz, 1H, H-8), 7.59 and 7.20 (2×t, J = 7.6 Hz, 1H, H-6), 7.52 and 7.36 (2×t, J = 7.6 Hz, 1H, H-7), 8.25 and 7.74 (2×s, 1H, H-2), 8.04 and 7.88 (2×d, J = 7.5 Hz, 1H, H-5), 10.01 and 9.52 (2×s, 1H, -NH), 11.37 and 10.88 (2×s, 1H, -NH). LC-MS m/z = 261 [M+1]; Anal. Calcd. for C₆H₁₂N₂O₃: C, 55.38; H, 4.65; N, 21.53; O, 18.44; Found: C, 55.46; H, 4.69; N, 21.66.

5-Oxo-5-(2-(quinazolin-4(3H)-ylidene)hydrazinyl)pentanoic acid (2d). Yield: 2.73 g (99%) (method C). Mp 133–135 °C; IR ν 3356 (νOH), 3204 (νNH), 2935 (νCH₃), 1705 (ν CO2), 1635 (ν CO), 1566 (δ NH), 1537, 1369, 1257, 792, 763, 684 cm⁻¹. ¹H NMR (400 MHz, DMSO-d₆) δ 1.87 (m, 2H, -CH₂CH₂CH₂-), 2.30 (2×s, 1H, -CH₂CH₂), 2.68 (m, 2H, -CH₂CH₂CH₂), 7.08 (d, J = 7.7 Hz, 1H, H-8), 7.50 and
3-Methyl-5-oxo-5-(2-(quinazolin-4(3H)-ylidene)hydrazinyl)pentanoic acid (2e). Yield: 2.86 g (99%) (method C). Mp 170–173 °C; IR 3724 (νOH), 3256 (νNH), 2928 (νCH), 1720 (νCO), 1600 (νCO), 1530 (δNH), 1371, 871, 760, 688 cm−1. 1H NMR (400 MHz, DMSO-d6) δ 1.03–1.01 (m, 3H, –CH2CH(CH3)2), 2.66–2.07 (m, 5H, –CH2CH(CH3)2CH2), 7.09 (d, J = 7.5 Hz, 1H, H-8), 7.19 (t, J = 6.6 Hz, 1H, H-6), 7.45–7.25 (m, 1H, H-7), 7.73 (s, 1H, H-2), 7.87 (d, J = 7.5 Hz, 1H, H-5), 9.93 and 9.50 (2×s, 1H, -NH2), 11.80 and 11.35 (2×s, 1H, -NH-). LC-MS m/z = 289 [M+1]; Anal. Calcd. for C13H14N4O3; C, 56.99; H, 5.21; N, 20.43; Found: C, 56.99; H, 5.21; N, 20.50.

2-(1-(2-Oxo-2-(2-(quinazolin-4(3H)-ylidene)hydrazinyl)ethyl)cyclopentyl)acetic acid (2f). Yield: 2.63 g (80%) (method C). Mp 189–191 °C; IR 3694 (νOH), 3256 (νNH), 2988 (νCH), 1703 (νCO), 1692 (δNH), 1520, 1329, 938 (δOH), 796, 668 cm−1. 1H NMR (400 MHz, DMSO-d6) δ 1.88–1.83 (m, 8H, –CH2(cyclopentyl)CH2), 2.90 and 2.45 (2×m, 4H, –CH2(cyclopentyl)CH2), 7.10 (d, J = 7.0 Hz, 1H, H-8), 7.24–7.14 (m, 1H, H-6), 7.45–7.29 (m, 1H, H-7), 7.75 (s, 1H, H-2), 7.85 (d, J = 7.4 Hz, 1H, H-5), 10.01 and 9.59 (2×s, 1H, -NH-), 11.90 and 11.40 (2×s, 1H, -NH-). LC-MS m/z = 329 [M+1]; Anal. Calcd. for C21H20N4O3: C, 62.18; H, 6.14; N, 17.06; Found: C, 62.23; H, 6.19; N, 17.12.

2. 2. General Method for the Synthesis of [(1,2,4]Triazolo[1,5-c]quinazolin-2-yl)carboxylic Acids and Their Esters (3a–b)

Method A. The solution of 5 mmol of corresponding quinazoline-containing hydrazide of dicarboxylic acid (2c–f) or ester (2a, 2b) in 20 mL of acetic acid was refluxed for 3–4 h with removing of formed water. After completing of reaction, the solvent was evaporated under vacuum. 30 mL of methanol was added to the residue and mixture was shaken. The formed precipitate was filtered, washed by 10 mL of ether and dried. For additional purification compounds 3a–f may be crystallized from ethanol (3a, 3b) or dioxane (3c–f).

Method B. 5.5 mmol of sodium acetate was added to the suspension of 0.8 g (5 mmol) of 4-hydrazinoquinazoline (1a) in 10 mL of glacial acetic acid. The formed mixture was cooled to 0–5 °C and 5.5 mmol of ethyl 2-chloro-2-oxoacetate or ethyl 3-chloro-3-oxopropanoate was added dropwise under stirring. The formed mixture was stirred for 1.5 h and then refluxed for 3 h. The formed precipitate of sodium chloride was filtered off, the solvent was evaporated under vacuum, 10 mL of methanol was added and formed mixture was shaken. The formed precipitate was filtered, washed by 10 mL of ether and dried. For additional purification compounds 3a–f may be crystallized from ethanol.

Method C. 5.5 mmol of corresponding dicarboxylic acid anhydride was added to the solution of 0.8 g (5 mmol) of 4-hydrazinoquinazoline (1a) in 20 mL of glacial acetic acid. The formed mixture was refluxed for 3–4 h with water removal. After completing of the reaction, the solvent was evaporated under vacuum, 10 mL of methanol was added and formed mixture was shaken. The formed precipitate was filtered off, washed by diethyl ether and dried. Compounds 3a–f may be additionally purified by crystallization from dioxane.

Compounds 3a, 3b that were synthesized by methods A and B have identical physicochemical properties.

Ethyl [(1,2,4]triazolo[1,5-c]quinazolin-2-yl]acrylate (3a). Yield: 1.03 g (85%) (method A), 0.87 g (72%) (method B). Mp 172–175 °C; IR 2920 (νCH2), 2851 (νCO), 1730 (νCO), 1625, 1517, 1458, 1363, 1201 (νCOO), 1019, 862, 780, 708, 654 cm−1. 1H NMR (400 MHz, DMSO-d6) δ 1.44 (t, J = 7.2 Hz, 3H, CH3), 4.46 (q, J = 7.1 Hz, 2H, CH2), 7.83 (t, J = 7.7 Hz, 1H, H-9), 7.92 (t, J = 7.7 Hz, 1H, H-8), 8.05 (d, J = 7.7 Hz, 1H, H-7), 8.54 (d, J = 7.7 Hz, 1H, H-10), 9.52 (s, 1H, H-5). LC-MS m/z = 243 [M+1]; Anal. Calcd. for C9H10N2O2: C, 59.50; H, 4.16; N, 23.13; Found: C, 59.58; H, 4.21; N, 23.19.

Ethyl (1,2,4]triazolo[1,5-c]quinazolin-2-yl)acetate (3b). Yield: 1.02 g (79%) (method A), 0.73 g (57%) (method B). Mp 125–127 °C; IR 2944 (νCH2), 1722 (νCO), 1621, 1524, 1370, 1219 (νCOO), 1026, 897, 774, 710, 668 cm−1. 1H NMR (400 MHz, DMSO-d6) δ 1.28 (t, J = 7.1 Hz, 3H, -CH3), 3.96 (s, 2H, -CH2H), 4.17 (q, J = 7.1 Hz, 2H, -CH2CH3), 7.77 (t, J = 7.5 Hz, 1H, H-9), 7.87 (t, J = 7.6 Hz, 1H, H-8), 8.02 (d, J = 8.2 Hz, 1H, H-7), 8.44 (d, J = 7.8 Hz, 1H, H-10), 9.40 (s, 1H, H-5). LC-MS m/z = 257 [M+1]; Anal. Calcd. for C10H11N2O2: C, 60.93; H, 4.72; N, 21.86; Found: C, 61.02; H, 4.80; N, 21.94.

3-[(1,2,4]Triazolo[1,5-c]quinazolin-2-yl)propanoic acid (3c). Yield: 1.20 g (99%) (method C). Mp 200–203 °C; IR 2900 (νCH2), 1723 (νCO), 1625, 1502, 1368, 1328, 1259, 1097 (δOH), 782, 710, 668 cm−1. 1H NMR (400 MHz, DMSO-d6) δ 2.82 (t, J = 7.3 Hz, 2H, -CH2CH2COOH), 3.18 (t, J = 7.2 Hz, 2H, -CH2CH2COOH), 7.71 (t, J = 7.6 Hz, 1H, H-9), 7.92 (t, J = 7.6 Hz, 1H, H-8), 7.98 (d, J = 7.7 Hz, 1H, H-7), 8.42 (d, J = 7.7 Hz, 1H, H-10), 9.26 (s, 1H, H-5), 11.90 (br. s, 1H, -COOH). LC-MS m/z = 243 [M+1]; Anal. Calcd. for C10H10N2O2: C, 59.50; H, 4.16; N, 23.13; Found: C, 59.56; H, 4.20; N, 23.21.

4-[(1,2,4]Triazolo[1,5-c]quinazolin-2-yl]butanoic acid (3d). Yield: 1.16 g (91%) (method C). Mp 184–186 °C; IR 2928 (νCH2), 1714 (νCO), 1625, 1521, 1404, 1366, 1329,
1241, 1181, 909 (δCH3), 792, 756, 711, 669 cm⁻¹. ¹H NMR (400 MHz, DMSO-d₆) δ 2.10 (m, 2H, -CН₂СН₂СН₂СООН), 3.74 (s, 3H, -OCOCH₃) δ 2.10 (m, 2H, -CН₂СН₂СН₂СООН), 3.00 (t, δ 7.2 Hz, 2H, -CH₂CH₂CH₂COOH), 2.18 (dd, J = 15.5 Hz, J = 8.1 Hz, 1H, H-8), 4.56 (d, J = 15.5 Hz, J = 4.9 Hz, 2H, -CH₂CH₂CH₂CH₂, 2.41 (t, J = 7.7 Hz, 1H, H-9), 8.00 (d, J = 7.7 Hz, 1H, H-7), 8.44 (d, J = 7.7 Hz, 1H, H-10), 9.37 (s, 1H, H-5), 11.82 (br. s, 1H, -COOH). LC-MS m/z = 257 [M+1]; Anal. Calcd. for C₁₃H₁₂N₄O₂: C, 60.93; H, 4.72; N, 21.86; Found: C, 60.99; H, 4.78; N, 21.94.

2-[(1,2,4]Triazolo[1,5-c]quinazolin-2-yl)-methyl)cyclopentanecarboxylic acid (3f). Yield: 0.79 g (51%) (method C). Mp 168–170 ºC; IR 2958 (νC=O), 1714 (νC=O), 1620, 1553, 1515, 1486, 1353, 1313, 1237, 931 (δ OH), 899, 774, 728, 698 cm⁻¹. ¹H NMR (400 MHz, DMSO-d₆) δ 1.86–1.42 (m, 8H, -CН₂(cyclopentyl)CH₂), 2.47–2.31 (m, 2H, -CH₂ cyclopentyl)CH₂), 3.17–3.05 (m, 2H, -CH₂(cyclopentyl)CH₂), 7.76 (t, J = 7.1 Hz, 1H, H-9), 7.86 (t, J = 7.0 Hz, 1H, H-8), 8.02 (d, J = 8.0 Hz, 1H, H-7), 8.45 (d, J = 7.7 Hz, 1H, H-10), 9.39 (s, 1H, H-5), 11.75 (s, 1H, -COOH). LC-MS m/z = 271 [M+1]; Anal. Calcd. for C₁₇H₁₄N₄O₃: C, 62.21; H, 5.22; N, 20.73; Found: C, 62.29; H, 5.31; N, 20.81.

2.3 General Method for the Synthesis of Amides of [(1,2,4]Triazolo[1,5-c]quinazolin-2-yl)alkylcarboxylic Acids (4a–j)

Method A. 5.5 mmol of para-methoxybenzylamine and 1–2 mL of DMF was added to the 5 mmol of corresponding ester (3a, 3b). The formed mixture was treated at 140–150 ºC for 3–4 h. The 5 mL of methanol and 5 mL of water were added to the mixture after completing of the reaction. The formed precipitate was filtered off and dried. Obtained compounds may be additionally purified by crystallization from ethanol.

Method B. 0.89 g (5.5 mmol) of N,N'-carbonyldiimidazole (CDI) was added to the solution of 5 mmol of corresponding carboxylic acid (3a–f) in 20 mL of anhydrous dioxane. The formed mixture was heated at 80 ºC for 1 h (until the carbon dioxide was completely released). Then 5 mmol of corresponding amine was added and stirred (or refluxed) for 1.5–3 h. The formed mixture was cooled and poured into water and acidified by hydrochloric acid to pH 5–6. The formed mixture was filtered off and dried.

N-(4-Methoxybenzyl)-[1,2,4]triazolo[1,5-c]quinazoline-2-carboxamide (4a). Yield: 0.97 g (58%). Mp 183–185 ºC; IR 3857 (νNH), 3753(νNH), 2928 (νC=O), 1553 (δNH), 1516, 1465, 1319, 1236, 741, 689 cm⁻¹. ¹H NMR (400 MHz, DMSO-d₆) δ 3.74 (s, 3H, -OCOCH₃), 4.47 (d, J = 5.7 Hz, 2H, -NHCH₂), 6.81 (d, J = 7.6 Hz, 2H, H-3,5), 7.29 (d, δ = 7.6 Hz, 1H, H-9), 7.92 (d, δ = 14.9 Hz, 1H, H-8), 8.07 (d, δ = 7.9 Hz, 1H, H-7), 8.29 (d, δ = 8.0 Hz, 1H, H-10), 9.06 (t, J = 5.4 Hz, 1H, -NHCH₂), 9.56 (s, 1H, H-5), LC-MS m/z = 334 [M+1]; Anal. Calcd. for C₁₇H₁₄N₄O₂: C, 64.86; H, 4.54; N, 21.01; Found: C, 64.93; H, 4.60; N, 21.09.

2-[(1,2,4]Triazolo[1,5-c]quinazolin-2-yl)-N-(4-methoxybenzyl)acetamide (4b). Yield: 1.20 g (69%). Mp 172–175 ºC; IR 3169 (νNH), 2920 (νC=O), 2851 (νC=O), 1669 (νC=O), 1547 (δNH), 1458, 1363, 1201, 1019, 862, 780, 708, 654 cm⁻¹. ¹H NMR (400 MHz, DMSO-d₆) δ 3.77 (s, 3H, -OCOCH₃), 4.45 (d, δ = 5.7 Hz, 2H, -NHCH₂), 6.87 (d, δ = 7.6 Hz, 2H, H-3,5), 7.22 (d, δ = 7.9 Hz, 2H, H-2,6-Bn), 7.63 (t, δ = 7.6 Hz, 1H, H-9), 7.78 (t, δ = 7.8 Hz, 1H, H-8), 8.00 (d, δ = 7.9 Hz, 1H, H-7), 8.43 (d, δ = 8.1 Hz, 1H, H-10), 9.08 (t, δ = 5.4 Hz, 1H, -NHCH₂), 9.38 (s, 1H, H-5), LC-MS m/z = 348 [M+1]; Anal. Calcd. for C₁₇H₁₄N₄O₂: C, 65.69; H, 4.93; N, 20.16; Found: C, 65.74; H, 4.98; N, 20.21.

3-[(1,2,4]Triazolo[1,5-c]quinazolin-2-yl)-N-(4-fluorophenyl)propionamide (4c). Yield: 1.07 g (64%). Mp 206–208 ºC; IR 3297 (νNH), 1665 (νC=O), 1530 (δNH), 1493, 1371, 1214, 901, 834, 767, 710 cm⁻¹. ¹H NMR (400 MHz, DMSO-d₆) δ 2.90 (t, δ = 7.6 Hz, 2H, -CH₂CH₂), 3.54–3.07 (m, 2H, -CH₂CH₂), 6.95 (t, δ = 8.6 Hz, 2H, H-3,5 Ph), 7.60 (dd, δ = 8.5 Hz, 2H, J = 4.9 Hz, 2H, H-2,6 Ph), 7.74 (t, δ = 7.5 Hz, 1H, H-9), 7.84 (t, δ = 7.7 Hz, 1H, H-8), 7.99 (d, δ = 8.1 Hz, 1H, H-7), 8.40 (d, J = 8.3 Hz, 1H, H-10), 9.95 (s, 1H, -NH₃), LC-MS m/z = 366 [M+1]; Anal. Calcd. for C₁₈H₁₄F N₂O₂: C, 64.47; H, 4.21; N, 20.88; Found: C, 64.54; H, 4.26; N, 20.93.

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Ethyl 4-(3-((1,2,4)triazolo[1,5-c]quinazolin-2-yl)propanamido)benzoate (4e). Yield: 1.18 g (61%). Mp 214–216 °C; IR 3857 (υNН), 3725 (υNН), 2901 (υCH2), 1711 (υCO), 1667 (υCO), 1599 (δСН), 1493, 1408, 1311, 894, 854, 766, 694 cm−1. 1H NMR (400 MHz, DMSO-d6) δ 1.85 (m, 2H, -(СН2)2), 2.06 (t, J = 7.6 Hz, 2H, -(СН2)2), 2.97 (t, J = 7.5 Hz, 2H, -(СН2)2), 3.25 (dd, J2 = 8.6 Hz, J3 = 6.7 Hz, 2H, -(СН2)2), 4.26 (q, J = 7.1 Hz, 1H, -СН2), 7.69 (s, J = 8.4 Hz, 2H, H-2,6 Ph), 7.73 (t, J = 7.6 Hz, 1H, H-9), 7.78–7.80 (m, 3H, H-8, H-3,5 Ph), 7.99 (d, J = 8.2 Hz, 1H, H-7), 8.40 (d, J = 7.5 Hz, 1H, H-10), 9.36 (s, 1H, -NH). LC-MS m/z = 390 [M+1]; Anal. Calcd. for C21H19N5O3: C, 64.77; H, 4.69; N, 19.14; Found: C, 65.39; H, 4.69; N, 19.19.

4-((1,2,4)Triazolo[1,5-c]quinazolin-2-yl)-N-(4-fluorophenyl)butanamide (4f). Yield: 0.78 g (45%). Mp 173–175 °C; IR 3295 (υNН), 3158 (υNН), 1658 (υCO), 1528 (δСН), 1504, 1432, 1404, 1336, 1207, 904, 835, 722, 669 cm−1. 1H NMR (400 MHz, DMSO-d6) δ 2.18 (p, J = 7.3 Hz, 2H, -(CH3)2CH2), 2.41 (t, J = 7.4 Hz, 2H, -(CH3)2CH2), 2.97 (t, J = 7.7 Hz, 2H, -(CH3)2CH2), 6.93 (t, J = 8.7 Hz, 2H, H-3,5 Ph), 7.56 (dd, J2 = 8.8 Hz, J3 = 5.0 Hz, 2H, H-2,6 Ph), 7.72 (t, J = 7.4 Hz, 1H, H-9), 7.85 (t, J = 7.7 Hz, 1H, H-7), 8.01 (d, J = 8.2 Hz, 1H, H-8), 8.43 (d, J = 7.8 Hz, 1H, H-10), 9.36 (s, 1H, H-5), 9.70 (s, 1H, -NH). LC-MS m/z = 366 [M+1]; Anal. Calcd. for C19H16F2N5O: C, 66.52; H, 4.62; N, 20.05; Found: C, 65.39; H, 4.69; N, 20.13.

4-((1,2,4)Triazolo[1,5-c]quinazolin-2-yl)-N-(4-chlorophenyl)butanamide (4g). Yield: 1.18 g (61%). Mp 196–198 °C; IR 3348 (υNН), 1657 (υCO), 1527 (δСН), 1491, 1465, 1338, 1283, 1250, 903, 821, 773, 703, 658 cm−1. 1H NMR (400 MHz, DMSO-d6) δ 1.05 (d, J = 6.6 Hz, 3H, -(CH3)2CH(=CH2)CH2), 2.26 (dd, J2 = 14.2 Hz, J3 = 8.2 Hz, 1H, -(CH3)2CH(=CH2)CH2), 2.44 (dd, 1H, J2 = 14.2 Hz, J3 = 8.2 Hz, -(CH2)2CH(=CH2)CH2), 2.65 (dq, J1 = 13.8 Hz, J2 = 8.2 Hz, 1H, -(CH2)2CH(=CH2)CH2), 2.84 (dd, J2 = 14.2 Hz, J3 = 8.2 Hz, 2H, -(CH2)2CH(=CH2)CH2), 2.98 (dq, J1 = 14.2 Hz, J2 = 6.2 Hz, 1H, -(CH2)2CH(=CH2)CH2), 7.16 (d, J = 8.7 Hz, 2H, H-3,5 Ph), 7.58 (d, J = 8.7 Hz, 2H, H-2,6 Ph), 7.74 (t, J = 7.6 Hz, 1H, H-9), 7.85 (t, J = 7.7 Hz, 1H, H-8), 8.00 (d, J = 8.1 Hz, 1H, H-7), 8.43 (d, J = 7.9 Hz, 1H, H-10), 9.35 (s, 1H, H-5), 9.84 (s, 1H, -NH). LC-MS m/z = 380 [M+1]; Anal. Calcd. for C22H21N5O3: C, 63.24; H, 4.78; N, 18.44; Found: C, 63.31; H, 4.83; N, 18.48.

2. 2. Anti-inflammatory Activity

Evaluation of anti-inflammatory activity of the synthesized compounds was conducted on 144 Wistar white rats (weight 150–160 g), obtained from the nursery «Institute of Pharmacology and Toxicology of Ukraine» (Kyiv). All experimental procedures and treatment were carried out according to the European Convention and «Regulations on the use of animals in biomedical research». Screening of the synthesized compounds with estimated anti-inflammatory activity began with the study of their effect on exudative phase of acute aseptic inflammation («carrageenan» test). Phlogogen (1% aqueous solution of λ-carrageenan) was subplantally injected in a dose of 0.1 mL in the rats' back right paw. The left one was used as a control. Intragastric administration of the studied compounds was conducted using atraumatic probe as water solution or finely dispersed suspension stabilized by Tween-80 in a dose of 10 mg/kg 1 h before the injection of phlogogen. The reference drug diclofenac sodium was administered intragastrically in a recommended dose of 8 mg/kg for pre-clinical studies. Measurement of paws volume was conducted before the experiment and in 4 h («carrageenan» test) after injection of phlogogen using the...
described methods. The activity of these substances was determined by their ability to reduce the swelling compared with control group and was expressed in percentage. It showed how the substance inhibited phlogogen swelling in relation to control swelling where the value was taken as 100%. The activity of the studied compounds was calculated as following:

\[
AA,\% = 100 \times \frac{V_{pe} - V_{he}}{V_{pc} - V_{hc}}
\]

(1)

where AA = anti-inflammatory activity, %; \(V_{pe}\) = the volume of paw edema in the experiment; \(V_{he}\) = the volume of healthy paw in the experiment; \(V_{pc}\) = the volume of paw edema in control; \(V_{hc}\) = the volume of healthy paw in control.

Statistical data processing was performed using a license program «STATISTICA® for Windows 10.0» (StatSoftInc., № AXXR712D833214FAN5) and «SPSS 16.0», «Microsoft Office Excel 360». The results are presented as mean ± standard error of the mean. Arithmetic mean and standard error of the mean were calculated for each of the studied parameters. During verification of statistical hypothesis, null hypothesis was declined if statistical criterion was \(p < 0.05\).24

3. Results and Discussion

Previously heterocyclization of corresponding (3H-quinazoline-4-ylidene)hydrazides was described as the most efficient and convenient method for 2-R-[1,2,4]triazolo[1,5-c]quinazolines synthesis.1–8 The preparation of the above-mentioned hydrazides is based on the acylation of 4-hydrazinoquinazoline by anhydrides, acyl halides, \(N\)-acyl imidazolides and other highly reactive derivatives of carboxylic acids.1–3 Namely, above-mentioned approaches were used for the synthesis of target compounds. It was found that initial compound 1a may be easily acylated in dioxane medium by ethyl 2-chloro-2-oxoacetate or ethyl 3-chloro-3-oxopropanoate (Method B) as well as by imidazolides of monoethyl esters of oxalic or malonic acids. Above-mentioned reaction yielded corresponding hydrazides (2a, 2b, Scheme 1). It should be noted that acylation by acyl halides required the presence of an organic base (triethylamine) and cooling of reaction medium to 0–5 °C. At the same time the reaction between 1a and corresponding imidazolides may be conducted under heating (80 °C). Hydrazides 2c–f, that contain prolonged alkyl moiety, were synthesized by interaction between initial compound 1a and cyclic anhydrides. Reaction was conducted in dioxane medium at ambient temperature or under heating (Method C, Scheme 1). The significant differences in yield values depending on the synthetic protocols used were not observed.

The following cyclization of hydrazides 2a–f yielded corresponding 2-(1,2,4)-triazolo[1,5-c]quinazoline-2-yl carboxylic acids and their esters (3a–f, Scheme 1). Besides, for compounds 3a–f one-pot synthesis method was elaborated. Thus compounds 3a and 3b were obtained via interaction of 4-hydrazinoquinazoline (1a) with above-mentioned acylhalides in acetic acid medium and the presence of sodium acetate at 0–5 °C followed by refluxing of reaction mixture for 3 h (Scheme 1). Compounds 3d–f were synthesized by reaction of compound 1a with cyclic anhy-
drizes in acetic acid. It should be noted that [1,2,4]triazolo[4,3-c]quinazolines played a role of intermediate products of condensation process. Above-mentioned intermediates underwent acid catalyzed Dimroth-type rearrangement that yielded isomeric [1,5-c]-series.1-3

Considering the presence of carboxylic or ester group in the structure of compounds 3 it was decided to conduct the chemical modification of above-mentioned fragment to obtain agents with higher anti-inflammatory activity. The synthesis of amides 4 was conducted by known methods, namely via aminolysis of esters 3a, 3b or imidazolides of acids 3c-f. Compounds 4a and 4b were obtained by fusing of initial esters 3a and 3b with 4-methoxybenzylamine at 130–140 °C. At the same time aminolysis of imidazolides of acids 3c-f occurred easily in anhydrous dioxane (Scheme 1).

Obtained compounds 2a-f, 3a-f, 4a-j are white, pale yellow crystalline powders that are not soluble in water, soluble in saturated aqueous solution of sodium (potassium) hydrocarbonates (3a-f), alcohols, dioxane and DMF.

Elemental analysis, 1H NMR and LS-MS data proved purity and structure of synthesized substances. The LC-MS using positive-ion atmospheric pressure chemical ionization (APCI) showed the appropriate molecular ions [M+1], 2a-f, 3a-f, 4a-j.

In 1H NMR spectra of hydrazides 2a-f the signals of endocyclic NH-protons and protons of hydrazide moiety were observed as broad or doublet at the 11.80-10.88 ppm and 11.11-9.48 ppm, correspondingly. The signals of protons in heterocyclic fragments were registered as a singlet at the 7.91-7.73 ppm (proton at the second position), doublets at the 8.02-7.73 ppm and 7.52-7.36 ppm (protons at the position 5 and positions 7, correspondingly), triplets at the 7.26-7.19 ppm and 7.17-7.08 ppm (protons at the position 6 and position 8, correspondingly). It should be mentioned that in some cases above-mentioned signals were broadened due to the hydrazide-hydrazonatotomerism.

1H NMR spectra of compounds 3a-f and 4a-j were characterized by the paramagnetic shift (relative to the 1H NMR spectra of compounds 2a-f) of the signals of the protons in heterocyclic moiety. Above-mentioned phenomenon may be explained by formation of electron-deficient heterocyclic system. The signal of proton at the position 5 of triazoloquinazoline system was characteristic for 1H NMR spectra of compounds 3a-f and was registered as a singlet at the 9.56-9.26 ppm.1-3 The other protons of tricyclic fragment formed ABCD system which consisted of sequentially located doublets and triplets with corresponding splitting constants.

The signal of carboxylic group protons was not observed in 1H NMR spectra of compounds 2c-f due to the deuterium exchanging processes. At the same time the signal of above-mentioned group protons was registered in low field as singlets at the 11.90-11.75 ppm in 1H NMR spectra of compounds 3c-f. In 1H NMR spectra of compounds 4a-j the chemical shifts of the signals of amide group proton depended on its chemical surrounding and were registered as triplets at the 9.08-9.06 ppm (compounds 4a, 4b) or singlets at the 10.21-9.70 ppm (4c-j). Besides, the signals of aromatic protons of benzylamide or anilide fragments were characteristic for 1H NMR spectra of compounds 4.25 In 1H NMR spectra of compounds 2, 3 and 4 the signals of aliphatic moieties protons were observed with corresponding chemical shifts and multiplicity.25 It should be noted that additional splitting of signals caused by diastereotopic methylene group protons of 3-methylbutyl fragment was observed in 1H NMR spectra of compounds 3e and 4j.

The characteristic bands of stretching vibrations of NH group at the 3256-3007 cm⁻¹, CO group at the 1741-1703 cm⁻¹, CONH group (“amide I” band) at the 1689-1600 cm⁻¹, “amide II” band at the 1615-1519 cm⁻¹ were present in IR spectra of compounds 2. IR spectra of compounds 3 were characterized by the absence of absorption bands caused by the stretching vibrations of amide group at the 3256-3007 cm⁻¹ and the presence of intensive bands of CO group stretching vibrations at the 1730-1706 cm⁻¹. IR spectra of compounds 4 were characterized by wide bands of NH group stretching vibrations at the 1669-1651 cm⁻¹, stretching vibrations bands of NH group at the 3857-3249 cm⁻¹, vibrations bands of CO group (“amide I”) at the 1669-1651 cm⁻¹ and combined stretching-deformation vibrations of NH and CN group (“amide II” band) at the 1599-1520 cm⁻¹. IR spectra of halogen-containing compounds were additionally characterized by absorption bands caused by stretching vibrations of C-halogen bond: νC-F at the 1110-1102 cm⁻¹ (4c, 4f), νC-Br at the 660–650 cm⁻¹ (4d, 4h), νC-Cl at the 750–700 cm⁻¹ (4g, 4j). It should be noted that in IR spectra of compounds 2, 3 and 4 low intensity bands νC=C at the 1468-1424 cm⁻¹, νC=O at the 1669-1651 cm⁻¹, νC-H2 and δCH2-group at the 2988-2928 and 1491-1404 cm⁻¹ were observed.

Screening of obtained compounds for anti-exudative activity was conducted in continuation of our studies aimed to the purposeful search of anti-inflammatory agents among compounds that contain heterocyclic fragment and carboxylic group. The studies were carried out using carrageenan-induced inflammation model.23 According to the obtained results (Table 1) in most of the cases obtained compounds were characterized by moderate anti-inflammatory activity. It should be noted that pharmacological effects of some compounds were comparable with activity of reference compound — sodium diclofenac. Thus, compounds 4a, 2b, 4e, 4g, 4h, 2e and 4j revealed anti-inflammatory activity on the level of 40.28-54.86%.

The conducted SAR-analysis showed that anti-exudative activity of hydrazides 2 depends on the length of alky moiety between heterocyclic fragment and carboxylic group. Compounds with propyl (2b), 3-methylpentyl (2e) and (cyclopentyl)ethyl (2f) fragments were the most
active among the compounds 2. Compounds 3 were less active comparing to hydrazides 2. Thus, cyclization of compounds 2 resulted in significant decrease of anti-inflammatory activity. At the same time amides 4 revealed high pharmacological effect. It was shown that level of anti-inflammatory activity depend on the nature of amide fragment. Amides that contain 4-chloro(bromo)phenyl moieties (4d, 4g, 4h, 4j) showed higher activity comparing to compounds 4e and 4i with “pharmacophore” 4-ethyl-carboxyphenyl fragment. The presence of 4-methoxybenzylamide moiety (compounds 4a and 4b) also had positive effect on the level of anti-inflammatory activity.

The conducted studies showed that amides of ([1,2,4]triazolo[1,5-c]quinazoline-2-yl)alkyl carboxylic acids are promising group of anti-inflammatory agents. The further study of their chemical modification and profound study of their pharmacological effects are reasonable in scope of purposeful search of novel effective anti-inflammatory drugs.

4. Conclusion

It was found that acylation of quinazolin-4(3H)-yldenedehydrazine by cyclic anhydrides of dicarboxylic acids, acylhalides or imidazolides of dicarboxylic acids monoesters is an efficient approach for the synthesis of corresponding hydrazides. The cyclization of obtained hydrazides yielded products that combine [1,2,4]triazolo[1,5-c]quinazoline fragment and carboxylic or ester groups in their structures. Above-mentioned compounds were used for the synthesis of corresponding amides. Screening of the synthesized compounds for anti-exudative activity revealed the potential of ([1,2,4]triazolo[1,5-c]quinazoline-2-yl)alkyl carboxylic acids amides as promising anti-inflammatory agents.

5. References

Povzetek
V prispevku opisujemo sintezo hidrazidov iz kinazolin-4(3H)-ilidenhidrazinov in dikarboksilnih kislin ter njihove nadaljnje transformacije. Pokazali smo, da tovrstne hidrazide lahko pripravimo s pomočjo aciliranja izhodnega kinazolin-4(3H)-ilidenhidrazina z ustreznimi acilhalidi, cikličnimi anhidridi in imidazoli monoestrov dikarboksilnih kislin. Pripravljene hidrazide smo pretvorili v [1,2,4]triazolo[1,5-c]kinazoline, ki smo jih uporabili kot izhodne spojine za nadaljnje kemijske modifikacije s ciljem uvedbe amidnega fragmenta v končne molekule. IR in 1H NMR spektroskopija ter sklopljena kromatografsko-masna spektrometrija so omogočile študij strukture produktov. Za pripravljene spojine smo določili tudi protivnetno učinkovitost s pomočjo modela vnetja podganje tačke s karaginanom. Zaključimo lahko, da so ([1,2,4]triazolo[1,5-c]kinazolin-2-il)alkil karboksilne kisline obetavna skupina molekuls s protivnetnim delovanjem, primerne za nadaljnje poglobljene študije sintez in protivnetnih aktivnosti.

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