Synthesis and antiproliferative activity of 2-((1,2,4)triazolo[4,3-b]pyridazin-6-yloxy)methyl)-2,4-dimethyl-3,4-dihydro-2H-benzo[b][1,4]oxazine derivatives

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Abstract
A small library of [1,2,4]triazolo[4,3-b]pyridazin-6-yloxy derivatives 14-17 of N-benzyl-N-(2-((4-amidinophenoxy)methyl)-2,4-dimethyl-3,4-dihydro-2H-benzo[b][1,4]oxazin-7-yl)oxalic acid monoamides 1 was prepared by replacement of benzamidine with a [1,2,4]triazolo[4,3-b]pyridazine-6-yl moiety. Thrombin inhibitory and fibrinogen receptor antagonistic activities inherent to benzamidine compounds 1 were lost in the [1,2,4]triazolo[4,3-b]pyridazine derivatives 14-17 which, on the other side, in their ester form (R2 = Et) inhibited the proliferation of endothelial and tumor cells.

Keywords: [1,2,4]Triazolo[4,3-b]pyridazine, 2,4-dimethyl-3,4-dihydro-2H-benzo[b][1,4]-oxazine, Mitsunobu reaction, benzamidine, thrombin inhibitor, cell proliferation

Introduction
Recently we have described a new series of potential antithrombotic compounds 1 based on a 2,4-dimethyl-3,4-dihydro-2H-benzo[b][1,4]oxazine scaffold possessing both thrombin inhibitory and fibrinogen receptor antagonistic activities.1 In an attempt to study structure-activity relationships and improve both their thrombin inhibitory activity and fibrinogen receptor binding affinity, we systematically introduced fluorine into different positions of the P3 benzyl group and replaced the basic benzamidino group present in 1 with [1,2,4]triazolo[4,3-b]pyridazine-6-yl moiety that could mimic the benzamidino part of the molecule (Figure 1). It is well documented that aromatic carbon-bound fluorine can participate in hydrogen bonding and electrostatic interactions2 thus contributing to the binding of drug molecules to their targets.3 Since many potent thrombin inhibitors possessing a highly basic benzamidino moiety lack oral
bioavailability,

this functionality has frequently been replaced by less basic N-heterocycles such as imidazo[1,2-a]pyridine,

indole,

indazole,

and pyrrolo[3,2-b]pyridine moieties. In our work, presented in this communication, introduction of fluorine into various positions of the aromatic ring of the P3 benzyl moiety improved the binding to both antithrombotic targets, whereas replacement of the benzamidine functionality in 1 by [1,2,4]triazolo[4,3-b]pyridazine-6-yl group to obtain analogues 14-17, had a detrimental effect on thrombin inhibition and platelet fibrinogen receptor binding. On the contrary, the antiproliferative activity of compounds studied on two endothelial (HMEC-1, BAEC) and two cancer (HELA, MCF-7) cell lines in connection with their antiangiogenic potential related to their thrombin inhibitory and fibrinogen receptor antagonistic activity, remained preserved in [1,2,4]triazolo[4,3-b]pyridazine compounds 14-17.

Figure 1. The general structure of compounds 14-17 derived from 1 by replacement of the benzamidine functionality with a [1,2,4]triazolo[4,3-b]pyridazine-6-yl moiety.

Results and Discussion

The synthesis of target [1,2,4]triazolo[4,3-b]pyridazine compounds 14-17 is depicted in Scheme 3. The key intermediate 2-hydroxymethylbenzo[b][1,4]oxazine derivative 9 was prepared as described, from 2-amino-5-nitrophenol 6 in three steps via i) cyclization affording ethyl 2,4-dimethyl-7-nitro-3-oxo-3,4-dihydro-2H-benzo[b][1,4]oxazine-2-carboxylate 7, ii) its N-methylation to 810 and iii) subsequent borane reduction1b of 8 (Scheme 2). 6-Chloro-[1,2,4]triazolo[4,3-b]pyridazine 4 was also obtained by a literature procedure, involving cyclization of 3-chloro-6-hydrazinylpyridazine 3 with diethyl ethoxymethylene malonate,11 and cyclization of 3 with triethyl orthoacetate afforded 6-chloro-3-methyl-[1,2,4]triazolo[4,3-b]pyridazine 512 (Scheme 1). As depicted in Scheme 3, substitution of chlorine in [1,2,4]triazolo[4,3-b]pyridazines 4 and 5 with alcoholate of 9 obtained in situ with sodium
hydride in N,N-dimethylformamide could be easily achieved to afford [1,2,4]triazolo[4,3-b]pyridazine-6-yl ethers 10a and 10b.

![Chemical Structures]

Scheme 1. Synthesis of compounds 4 and 5. Reagents and conditions: a: hydrazine hydrate, 25% aq. NH₃ (ref. 13); b: EtOCH=C(COOEt)₂, CH₃CN, reflux, 3 h; c: CH₃C(OEt)₃, reflux, 12 h.

Scheme 2. Synthesis of 9. Reagents and conditions: a: Br(Me)C(COOEt)₂, KF, DMF, 60 °C, 6 h; b: MeI, toluene, reflux, 2 h; c: BH₃·Me₂S, THF, reflux, 12 h.

After their reduction to amino derivatives 11a and 11b, N-benzylation at the aromatic amino group was carried out via imines formed with benzaldehyde, 4-fluorobenzaldehyde or 3,5-difluorobenzaldehyde, and their reduction using sodium borohydride to give compounds 12a-c and 13a-c. Acylation of amines 12 and 13 with ethyloxyalyl chloride led to carboxamides 14a-c and 15a-c, respectively. Finally, hydrolysis of the ethyl esters with 1M lithium hydroxide gave the corresponding carboxylic acids 16a-c and 17a-c.

Compounds 14-17 were tested for thrombin inhibition according to a previously described protocol¹ᵇ and found to be devoid of thrombin inhibitory activity (Kᵢ > 300 μM; results not shown) indicating that in this compound class substitution of the benzamidine with a [1,2,4]triazolo[4,3-b]pyridazin-6-yl moiety is detrimental for thrombin inhibition. Also the affinity for binding to platelet fibrinogen receptor tested according to a published procedure¹ᵇ was lost (IC₅₀ > 100 μM; results not shown), indicating again that in this type of compound for preservation of fibrinogen receptor antagonistic activity the benzamidine moiety cannot be replaced by a [1,2,4]triazolo[4,3-b]pyridazine core.
Scheme 3. Synthesis of compounds 14 - 17. Reagents and conditions: 
a: 60% NaH, 4 or 5, DMF, 100 °C, 12 h; 
b: H₂, Pd/C, MeOH, r.t., 25 bar, 1 h; 
c: benzaldehyde/4-fluorobenzaldehyde/3,5-difluorobenzaldehyde, MeOH, r.t., 12 h, then NaBH₄, r.t., 12 h; 
d: EtOCOCOCl, Et₃N, CH₂Cl₂, r.t., 2 h; 
e: 1M LiOH, THF/MeOH, r.t., 2 h.

In order to evaluate the antiangiogenic potential of [1,2,4]triazolo[4,3-b]pyridazine analogs 14-17 and compare it to established antiangiogenic activity of compounds 1, their in vitro effects on the growth of human microvascular endothelial cells (HMEC-1), bovine aortic endothelial cells (BAEC), human cervical carcinoma cells (HELA) and human breast carcinoma cells (MCF-
7) were assessed. The results collected in Table 1 indicate that esters 14a-c and 15a-c inhibit the proliferation of both endothelial (HMEC and BAEC) cell lines and both carcinoma (HELA and MCF-7) cell lines, with IC<sub>50</sub> values ranging from 36.6 to 46.0 μM for HMEC-1, 33.5 to 38.0 μM for BAEC, 31.2 to 39.3 μM for HELA and 9.8 to 24.2 μM for MCF-7 cell lines, and were roughly 10-fold less potent than esters 1. A combination of ionic structures (amidinium ion) with lipophilic parts very often gives rise to inhibition of cell growth, which may account for the higher activity of the amidine derivatives in cell proliferation assays. The carboxylic acids 16a-c and 17a-c were devoid of anti-proliferative activity, suggesting their insufficient cellular uptake. Compounds 14a-c and 15a-c were weakly active in cell migration assay but proved to be inactive in tube formation assay and chorioallantoic membrane (CAM) assay (data not shown), whereas carboxylic acids 16a-c and 17a-c did not show any activity in these three assays.

<table>
<thead>
<tr>
<th>Compound</th>
<th>HMEC-1 (IC&lt;sub&gt;50&lt;/sub&gt;, μM)</th>
<th>BAEC (IC&lt;sub&gt;50&lt;/sub&gt;, μM)</th>
<th>HELA (IC&lt;sub&gt;50&lt;/sub&gt;, μM)</th>
<th>MCF-7 (IC&lt;sub&gt;50&lt;/sub&gt;, μM)</th>
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<tr>
<td>14a</td>
<td>46.0 ± 0.5</td>
<td>37.3 ± 2.5</td>
<td>36.9 ± 2.5</td>
<td>24.2 ± 3.5</td>
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<tr>
<td>16a</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
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<tr>
<td>14b</td>
<td>45.3 ± 2.6</td>
<td>37.3 ± 3.0</td>
<td>37.0 ± 5.2</td>
<td>13.6 ± 1.9</td>
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<tr>
<td>16b</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
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<tr>
<td>14c</td>
<td>39.1 ± 2.9</td>
<td>36.7 ± 3.6</td>
<td>34.2 ± 4.4</td>
<td>18.6 ± 1.3</td>
</tr>
<tr>
<td>16c</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>15a</td>
<td>44.7 ± 0.7</td>
<td>36.3 ± 4.8</td>
<td>39.3 ± 6.8</td>
<td>16.1 ± 0.7</td>
</tr>
<tr>
<td>17a</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
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<tr>
<td>15b</td>
<td>38.4 ± 0.4</td>
<td>38.0 ± 2.3</td>
<td>31.2 ± 12.3</td>
<td>9.8 ± 1.8</td>
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<tr>
<td>17b</td>
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<td>&gt; 100</td>
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<td>33.5 ± 6.9</td>
<td>33.7 ± 2.1</td>
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<td>17c</td>
<td>&gt; 100</td>
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</table>

**Conclusions**

Compounds 14 - 17 were synthesized as analogues of potential dual antithrombotic compounds 1 possessing thrombin inhibitory and fibrinogen receptor antagonistic activity. The replacement of the benzamidine functionality of compounds 1 with a [1,2,4]triazolo[4,3-b]pyridazine moiety resulted in loss of thrombin inhibitory and fibrinogen receptor antagonistic activity. However, anti-proliferative activity against HMEC-1, BAEC, HELA and MCF-7 cell lines inherent to
benzamidines 1 was retained in esters 14a-c and 15a-c, indicating that this activity may not be attributed to the presence of a basic benzamidino group.

**Experimental Section**

**General.** Chemicals were obtained from Acros, Sigma-Aldrich, Fluka and Alfa Aesar and used without further purification. Hydrogenation reactions were carried out using a Parr 4842 hydrogenation apparatus. Analytical TLC was performed on silica gel Merck 60 F254 plates (0.25 mm), using visualization with ultraviolet light. Column chromatography was carried out on silica gel 60 (particle size 240-400 mesh). Melting points were determined on a Reichert hot stage microscope and are uncorrected. 1H-NMR and 13C-NMR spectra were recorded on a Bruker AVANCE III spectrometer (400 MHz for 1H and 100 MHz for 13C nuclei) in DMSO-d6 solution with TMS as the internal standard. The coupling constants (J) are given in Hz, and the splitting patterns are appointed as: s (singlet), d (doublet), dd (double doublet), t (triplet) and m (multiplet). IR spectra were recorded on a Perkin-Elmer 1600 FT-IR spectrometer. Microanalyses were performed at University of Ljubljana, Faculty of Chemistry and Chemical Technology on a Perkin-Elmer C, H, N analyzer 240 C. Mass spectra were obtained at Jožef Stefan Institute, Ljubljana, using a VG-Analytical Autospec Q mass spectrometer. HPLC analyses were performed on an Agilent Technologies HP 1100 instrument with G1365B UV-VIS detector (254 nm), using an Eclips Plus C18 column (4.6 x 150 mm) at flow rate 1 mL/min. The eluant was a mixture of 0.1 % TFA in water (A) and methanol (B). Gradient was 40% B to 80% B in 15 minutes. Purification of final compounds, if necessary, was performed by reverse phase column chromatography using a Flash Purification System ISOLERA™ with 0.1 % TFA in water and methanol as an eluent.**

**Synthesis of compounds 7, 8 and 9** and [1,2,4]triazolo[4,3-b]pyridazine building blocks 4-611-13 were performed according to published synthetic procedures.

**General procedure for the synthesis of compounds (10a) and (10b)**

Compound 9 (7.70 g, 32.3 mmol) was dissolved in 100 ml absolute DMF and 60% NaH (1.4 g, 58.1 mmol) was added. The mixture was stirred for 1 h at room temperature under argon atmosphere, whereupon 6-chloro-[1,2,4]triazolo[4,3-b]pyridazine 4 (5.0 g, 32.3 mmol) was added. The mixture was stirred for 2 h at room temperature, then at 110 ºC overnight. Product 10a was purified by column chromatography using DCM/MeOH 20:1 as eluent, to afford 10.1 g (88% yield) of 10a of yellow powder.

2-(([1,2,4]Triazolo[4,3-b]pyridazin-6-yl oxy)methyl)-2,4-dimethyl-7-nitro-3,4-dihydro-2H-1,4-benzoxazine (10a). Yellow powder, yield: 88%; mp 166-168 ºC; 1H NMR (400 MHz, DMSO-d6): δ 1.43 (s, 3H, 2-CH3), 3.08 (s, 3H, N-CH3), 3.37-3.41 (d, overla ped with water, 1H, 3-H), 3.61 (d, J 12.6 Hz, 1H, 3-H), 4.37 (d, J 11.3 Hz, 1H, CH2O), 4.40 (d, J 11.2 Hz, 1H, CH2O), 6.85 (d, J 9.2 Hz, 1H, Ar-H5), 7.13 (d, J 9.8 Hz, 1H, Ar-H7), 7.48 (d, J 2.6 Hz, 1H, Ar-
H^3), 7.80 (dd, J 9.1, 2.6 Hz, 1H, Ar-H^6), 8.30 (dd, J 9.8, 0.8 Hz, 1H, Ar-H^8), 9.39 (d, J 0.7 Hz, 1H, Ar-H^3); \(^1^3^C\) NMR (DMSO-d_6): \(\delta\) 143.0, 141.7, 140.7, 139.4, 137.1, 127.1, 119.5, 117.1, 111.3, 110.6, 73.9, 69.9, 53.3, 38.6, 31.2, 20.8; HRMS (ESI) \(m/z\) calcd for C\(_{16}\)H\(_{17}\)N\(_2\)O\(_4\) [M + H]\(^+\) 357.1311, found 357.1312; IR (KBr) \(v_{\text{max}}/\text{cm}^{-1}\): 3447, 3129, 1601, 1497, 1302, 1018, 830; HPLC: 98.4%, \(t\) 11.6 min; Anal. Calcd. for C\(_{16}\)H\(_{16}\)N\(_2\)O\(_4\) × 1/2 H\(_2\)O: C, 53.45; H, 4.50; N, 23.58. Found: C, 53.48; H, 4.58; N, 23.39%.

2,4-Dimethyl-2-(((3-methyl-[1,2,4]triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-7-nitro-3,4-dihydro-2H-1,4-benzoazaine (10b). Yellow powder, yield: 84%; mp 121-123 °C; \(^1^H\) NMR (400 MHz, DMSO-d_6): \(\delta\) 1.42 (s, 3H, 2-CH\(_3\)), 2.52 (s, 3H, 3'-CH\(_3\)), 3.07 (s, 3H, N-CH\(_3\)), 3.36-3.40 (d, overlapped with water, 1H, 3-H), 3.60 (d, J 12.6 Hz, 1H, 3-H), 4.40 (d, J 11.3 Hz, 1H, CH\(_2\)O), 4.47 (d, J 11.3 Hz, 1H, CH\(_2\)O), 6.83 (d, J 9.2 Hz, 1H, Ar-H^5), 7.05 (d, J 9.8 Hz, 1H, Ar-H^3), 7.42 (d, J 2.6 Hz, 1H, Ar-H^8), 7.78 (dd, J 9.1, 2.6 Hz, 1H, Ar-H^6), 8.23 (d, J 9.8 Hz, 1H, Ar-H^8); \(^1^3^C\) NMR (DMSO-d_6): \(\delta\) 160.4, 146.4, 143.2, 141.8, 140.8, 137.0, 127.2, 119.4, 116.0, 111.3, 110.6, 74.1, 69.6, 43.3, 38.6, 20.9, 9.6; HRMS (ESI) \(m/z\) calcd for C\(_{17}\)H\(_{19}\)N\(_2\)O\(_4\) [M + H]\(^+\) 371.1468, found 371.1462; IR (KBr) \(v_{\text{max}}/\text{cm}^{-1}\): 3606, 3340, 1599, 1502, 1291, 1073, 879; HPLC: 100%, \(t\) 12.3 min; Anal. Calcd. for C\(_{17}\)H\(_{18}\)N\(_2\)O\(_4\) × 1/2 H\(_2\)O: C, 53.53; H, 5.21; N, 22.23. Found: C, 53.82; H, 5.05; N, 22.15%.

General procedure for reduction of compounds (10a) and (10b) by catalytic hydrogenation

The hydrogenation reaction was performed in a hydrogenator (25 bar, 1 h, 10% Pd/C). A mixture of compound 10a (9.0 g, 24.3 mmol) dissolved in 100 ml MeOH and 10% Pd/C (0.9 g) was stirred at room temperature till the reaction was completed (1 h). The catalyst was filtered off and the solvent was evaporated in vacuo to yield 8.3 g (100%) of 11a.

2-(((1,2,4)Triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-2,4-dimethyl-3,4-dihydro-2H-1,4-benzoazaine-7-amine (11a) and 2,4-dimethyl-2-(((3-methyl-[1,2,4]triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-3,4-dihydro-2H-1,4-benzoazaine-7-amine (11b) were used in the next step without further purification.

General procedure for reductive amination (aldimine formation/reduction) of compounds (11a) and (11b)

Benzaldehyde (2.4 g, 22.3 mmol), amine 11a (8 g, 24.6 mmol) and molecular sieves (0.3 nm) were mixed in 100 ml absolute methanol at room temperature under argon atmosphere. The mixture was stirred overnight until the aldimine formation was complete. The aldimine in methanol was carefully treated with solid NaBH\(_4\) (1.6 eq, 35.7 mmol, 1.3 g) and the reaction mixture was stirred for additional 2 h. The solvent was removed in vacuo and the crude product isolated by extraction with dichloromethane (DCM). The product was purified by column chromatography using DCM/MeOH 20:1 as eluent to afford 12a as yellow powder (5.2 g, yield 51%).
MHZ, DMSO-d6): δ 1.39 (s, 3H, 2-CH3), 2.70 (s, 3H, N-CH3), 2.84 (d, J 9.8 Hz, 1H, 3-H), 3.15 (d, J 9.9 Hz, 1H, 3-H), 4.15 (s, 2H, Ph-CH2), 4.32 (s, 2H, CH2O), 5.70 (s, 1H, NH), 5.96-6.23 (m, 2H, Ar-H3, Ar-H6), 6.55 (s, 1H, Ar-H8), 7.13 (d, J 9.9 Hz, 1H, Ar-H7), 7.16-7.38 (m, 5H, Ph), 8.28 (dd, J 9.8, 0.8 Hz, 1H, Ar-H8), 9.39 (d, J 0.8 Hz, 1H, Ar-H3); 13C NMR (DMSO-d6): δ 160.9, 143.0, 142.1, 139.4, 138.1, 137.7, 132.8, 128.7, 127.6, 127.0, 126.9, 126.7, 125.4, 122.4, 117.2, 115.7, 110.2, 76.4, 62.6, 53.8, 38.0, 20.7, 13.3; HRMS (ESI) m/z calcd for C23H24NO2 [M+H]+ 416.1961, found 416.1960; IR (KBr) νmax/cm⁻¹: 3392, 2808, 1627, 1518, 1297, 1019, 819; HPLC: 97.9%, tR 8.4 min.

2-(((1,2,4)Triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-N-(4-fluorobenzyl)-2,4-dimethyl-3,4-dihydro-2H-1,4-benzoxazin-7-amine (12b). Yellow powder, yield 5.8 g (54%); mp 66-68 °C; ¹H NMR (400 MHz, DMSO-d6): δ 1.39 (s, 3H, 2-CH3), 2.70 (s, 3H, N-CH3), 2.84 (d, J 9.9 Hz, 1H, 3-H), 3.16 (d, J 9.8 Hz, 1H, 3-H), 4.12 (s, 2H, Ph-CH2), 4.32 (d, J 11.0 Hz, 1H, CH2O), 4.44 (d, J 11.0 Hz, 1H, CH2O), 5.72 (s, 1H, NH), 5.89-6.20 (m, 2H, Ar-H3, Ar-H6), 6.55 (s, 1H, Ar-H8), 7.05-7.17 (m, 3H, Ph, Ar-H7), 7.28-7.40 (m, 2H, Ph), 8.28 (dd, J 9.8, 0.8 Hz, 1H, Ar-H8), 9.39 (d, J 0.8 Hz, 1H, Ar-H7); 13C NMR (DMSO-d6): δ 162.6, 160.9, 160.2, 146.2, 143.0, 139.4, 129.4, 129.4, 127.0, 117.2, 115.5, 115.3, 111.2, 111.0, 103.4, 103.1, 102.8, 74.1, 61.1, 53.1, 50.2, 38.0, 20.7; HRMS (ESI) m/z calcd for C23H23FNO2 [M+H]+ 434.1867, found 434.1868; IR (KBr) νmax/cm⁻¹: 3344, 3064, 2810, 1627, 1508, 1333, 1217, 1016, 819; HPLC: 96.2%, tR 8.8 min.

2-(((1,2,4)Triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-N-(3,5-difluorobenzyl)-2,4-dimethyl-3,4-dihydro-2H-1,4-benzoxazin-7-amine (12c). Yellow powder, yield 5.4 g (49%); mp 71-73 °C; ¹H NMR (400 MHz, DMSO-d6): δ 1.39 (s, 3H, 2-CH3), 2.71 (s, 3H, N-CH3), 2.86 (d, J 9.8 Hz, 1H, 3-H), 3.16 (d, J 9.8 Hz, 1H, 3-H), 4.19 (s, 2H, Ph-CH2), 4.32 (s, 2H, CH2O), 5.86 (s, 1H, NH), 5.92-6.19 (m, 2H, Ar-H3, Ar-H6), 6.56 (d, J 6.3 Hz, 1H, m, 2H, Ar-H8), 7.00-7.08 (m, 3H, Ph), 7.13 (d, J 9.8 Hz, 1H, Ar-H7), 8.28 (dd, J 9.8, 0.8 Hz, 1H, Ar-H8), 9.39 (d, J 0.8 Hz, 1H, Ar-H7); 13C NMR (DMSO-d6): δ 162.3, 160.9, 146.3, 142.9, 139.4, 129.3, 129.1, 127.0, 117.2, 115.1, 115.0, 111.9, 111.1, 104.1, 103.9, 102.8, 74.0, 62.5, 60.1, 53.8, 38.2, 20.7, 13.3; HRMS (ESI) m/z calcd for C23H23F2NO2 [M+H]+ 453.1851, found 453.1840; IR (KBr) νmax/cm⁻¹: 3380, 2810, 1630, 1515, 1333, 1302, 1179, 1020, 818; HPLC: 96.8%, tR 9.0 min.

N-Benzyl-2,4-dimethyl-2-(((3-methyl-[1,2,4]triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-3,4-dihydro-2H-1,4-benzoxazin-7-amine (13a): Yellow powder, yield 5.2 g (51%); mp 81-83 °C; ¹H NMR (400 MHz, DMSO-d6): δ 1.39 (s, 3H, 2-CH3), 2.52 (s, 3H, 3'-CH3), 2.85 (d, J 11.0 Hz, 1H, 3-H), 3.16 (d, J 11.1 Hz, 1H, 3-H), 3.38 (s, 3H, N-CH3); 4.11 (s, 2H, Ph-CH2), 4.31 (d, J 10.4 Hz, 1H, CH2O), 4.43 (d, J 10.3 Hz, 1H, CH2O), 5.69 (s, 1H, NH), 5.84-6.21 (m, 2H, Ar-H3, Ar-H6), 6.55 (s, 1H, Ar-H8), 7.06 (d, J 9.8 Hz, 1H, Ar-H7), 7.16-7.36 (m, 5H, Ph), 8.21 (d, J 9.8 Hz, 1H, Ar-H8); 13C NMR (DMSO-d6): δ 160.5, 160.2, 146.6, 143.7, 143.2, 141.9, 137.0, 128.7, 127.6, 127.0, 126.9, 116.1, 116.0, 115.5, 114.9, 114.0, 106.1, 102.8, 74.8, 69.2, 55.9, 47.0, 21.7, 9.7; HRMS (ESI) m/z calcd for C24H27N6O2 [M+H]+ 431.2198, found 431.2178; IR (KBr) νmax/cm⁻¹: 3385, 3057, 2808, 1627, 1519, 1299, 1180, 1017, 818; HPLC: 96.4%, tR 9.3 min.

N-(4-Fluorobenzyl)-2,4-dimethyl-2-(((3-methyl-[1,2,4]triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-3,4-dihydro-2H-1,4-benzoxazin-7-amine (13b). Yellow powder, yield 5.1 g (48%);
mp 80-82 °C; 1H NMR (400 MHz, DMSO-d6): δ 1.39 (s, 3H, 2-CH3), 2.70 (s, 3H, 3’-CH3), 2.84 (d, J 11.5 Hz, 1H, 3-H), 3.16 (d, J 11.4 Hz, 1H, 3-H), 3.38 (s, 3H, N-CH3), 4.09 (d, J 5.3 Hz, 2H, Ph-CH2), 4.31 (d, J 10.9 Hz, 1H, CH2O), 4.43 (d, J 10.9 Hz, 1H, CH2O), 5.69 (t, J 5.7 Hz, 1H, NH), 5.94 (d, J 2.4 Hz, 1H, Ar-Hδ), 6.12 (dd, J 8.6, 2.5 Hz, 1H, Ar-Hδ), 6.56 (d, J 8.6 Hz, 1H, Ar-Hδ), 7.06 (d, J 9.8 Hz, 1H, Ar-Hδ), 7.09-7.16 (m, 2H, Ph), 7.27-7.38 (m, 2H, Ph), 8.21 (d, J 9.8 Hz, 1H, Ar-Hδ); 13C NMR (DMSO-d6): δ 162.6, 160.5, 160.2, 146.6, 144.1, 143.2, 142.7, 137.3, 129.4, 129.3, 127.1, 126.7, 116.1, 115.5, 115.3, 114.4, 106.2, 101.3, 75.0, 70.2, 55.5, 46.8, 21.7, 9.7; HRMS (ESI) m/z calcd for C24H20F2N2O2 [M + H]+ 467.2001, found 467.2010; IR (KBr) νmax/cm-1: 3368, 3064, 2810, 1625, 1517, 1300, 1094, 1014, 820; HPLC: 95.7%, t 9.7 min.

N-(3,5-Difluorobenzyl)-2,4-dimethyl-2-(((3-methyl-[1,2,4]triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-3,4-dihydro-2H-1,4-benzoazin-7-amine (13c). Yellow powder, yield 6.0 g (51%); mp 80-82 °C; 1H NMR (400 MHz, DMSO-d6): δ 1.39 (s, 3H, 2-CH3), 2.71 (s, 3H, 3’-CH3), 2.86 (d, J 11.5 Hz, 1H, 3-H), 3.17 (d, J 11.5 Hz, 1H, 3-H), 3.38 (s, 3H, N-CH3), 4.16 (d, J 5.5 Hz, 2H, Ph-CH2), 4.32 (d, J 10.9 Hz, 1H, CH2O), 4.42 (d, J 10.9 Hz, 1H, CH2O), 5.83 (t, J 6.0 Hz, 1H, NH), 5.96 (d, J 2.4 Hz, 1H, Ar-Hδ), 6.10 (dd, J 8.6, 2.4 Hz, 1H, Ar-Hδ), 6.56 (d, J 8.7 Hz, 1H, Ar-Hδ), 6.96-7.11 (m, 4H, Ph, Ar-Hδ), 8.21 (d, J 9.8 Hz, 1H, Ar-Hδ); 13C NMR (DMSO-d6): δ 160.5, 146.6, 144.1, 143.2, 142.2, 127.1, 126.9, 116.1, 114.5, 110.4, 110.4, 110.3, 110.2, 106.2, 102.6, 102.3, 102.1, 101.4, 75.0, 70.3, 55.4, 46.7, 21.7, 9.7; HRMS (ESI) m/z calcd for C26H22F2N2O2 [M + H]+ 472.1350, found 472.1344; IR (KBr) νmax/cm-1: 3385, 3056, 2812, 1624, 1518, 1302, 1188, 1016, 819; HPLC: 98.0%, t 10.8 min.

General procedure for preparation of N-acylated compounds (14a-c) and (15a-c)

Ethyl oxaloyl chloride (1.6 g, 11.5 mmol) was added to a solution of compound 12a (4.0 g, 9.6 mmol) and triethylamine (1.2 g, 11.5 mmol) in dichloromethane (70 ml) and the mixture stirred for 2 h. The solvent was removed under reduced pressure, the residue dissolved in ethyl acetate (50 ml) and washed successively with a 10% citric acid solution (3 x 50 ml), saturated NaHCO3 solution (3 x 50 ml) and brine (1 x 50 ml). The organic phase was dried over Na2SO4 and the solvent evaporated under reduced pressure. The oily product was purified by column chromatography using petroleum ether/ethyl acetate (1.5:1) as eluent to afford 14a as a white powder (2.9 g, yield 58%).

**Ethyl 2-((2-((1,2,4)triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-2,4-dimethyl-3,4-dihydro-2H-1,4-benzoazin-7-yl)(benzyl)amino)-2-oxoacetate (14a).** White powder, yield 2.9 g (58%); mp 70-72 °C; 1H NMR (400 MHz, DMSO-d6): δ 0.80 (t, J 7.1 Hz, 3H, CH2CH3), 1.39 (s, 3H, 2-CH3), 2.84 (s, 3H, N-CH3), 3.08 (d, J 11.9 Hz, 1H, 3-H), 3.34 (d, J 11.9 Hz, 1H, 3-H), 3.92 (q, J 7.1 Hz, 2H, CH2CH3), 4.32 (d, J 11.1 Hz, 1H, CH2O), 4.28 (d, J 11.1 Hz, 1H, CH2O), 4.84 (s, 2H, Ph-CH2), 6.52-6.59 (m, 2H, Ar-H5, Ar-Hδ), 6.67 (d, J 8.4 Hz, 1H, Ar-Hδ), 7.11 (d, J 9.8 Hz, 1H, Ar-Hδ), 7.14-7.34 (m, 5H, Ph), 8.29 (d, J 9.8 Hz, 1H, Ar-Hδ), 9.40 (s, 1H, Ar-Hδ); 13C NMR (DMSO-d6): δ 162.6, 161.7, 160.4, 142.5, 141.9, 138.9, 136.3, 135.2, 129.0, 128.5, 127.8, 127.4, 126.5, 120.5, 116.6, 115.4, 115.2, 114.8, 111.8, 74.0, 69.8, 61.0, 53.3, 51.0, 38.0, 20.5, 13.3;
HRMS (ESI) m/z calcld for C_{27}H_{29}N_{6}O_{5} [M + H]^+ 517.2199, found 517.2207; IR (KBr) ν_{max}/cm\(^{-1}\): 3447, 2980, 1740, 1663, 1518, 1298, 1193, 1021, 818; HPLC: 100 %, t = 15.3 min; Anal. Calcd. for C_{27}H_{29}N_{6}O_{5} × ½ H_2O: C, 61.91; H, 5.48; N, 15.99. Found: C, 61.70; H, 5.56; N, 15.99%.

**Ethyl 2-(((1,2,4)triazolo[4,3-b]pyridazin-6-yloxy)methyl)-2,4-dimethyl-3,4-dihydro-2H-1,4-benzoazoxan-7-yl(4-fluorobenzyl)(3,5-difluorobenzyl)(amino)-2-oxoacetate (14b).** White powder, yield 2.6 g (52%); mp 73-75 °C; \(^1\)H NMR (400 MHz, DMSO-d_6): δ 0.72 (t, J 7.1 Hz, 3H, CH_2CH_3), 1.32 (s, 3H, 2-CH_3), 2.78 (s, 3H, N-CH_3), 3.01 (d, J 11.9 Hz, 1H, 3-H), 3.27 (d, overlapped with water, 1H, 3-H), 3.84 (q, J 7.1 Hz, 2H, CH_2CH_3), 4.22 (d, J 11.1 Hz, 1H, CH_2O), 4.26 (d, h 11.1 Hz, 1H, CH_2O), 4.76 (s, 2H, Ph-CH_2), 6.44-6.51 (m, 2H, Ar-H^δ, Ar-H^δ), 6.60 (d, J 8.3 Hz, 1H, Ar-H^δ), 7.02-7.11 (m, 3H, Ph-H^δ, H^5, Ar-H^7), 7.11-7.17 (m, 2H, Ph-H^2, H^6), 8.22 (d, J 9.8 Hz, 1H, Ar-H^6), 9.34 (s, 1H, Ar-H^3); \(^13\)C NMR (DMSO-d_6): δ 162.5, 161.7, 160.4, 142.5, 141.9, 138.9, 135.2, 132.6, 132.5, 130.0, 129.9, 128.7, 126.6, 120.6, 116.6, 115.4, 115.2, 114.8, 111.8, 73.9, 69.8, 61.0, 53.3, 50.1, 38.0, 20.5, 15.3, 13.3; HRMS (ESI) m/z calcld for C_{27}H_{29}F_{2}N_{6}O_{5} [M + H]^+ 535.2105, found 535.2118; IR (KBr) ν_{max}/cm\(^{-1}\): 3447, 2981, 1741, 1664, 1509, 1219, 1022, 820; HPLC: 100 %, t = 15.6 min; Anal. Calcd. for C_{27}H_{29}F_{2}N_{6}O_{5} × ½ H_2O: C, 59.87; H, 5.14; N, 15.21. Found: C, 59.66; H, 5.19; N, 15.46%.

**Ethyl 2-(((1,2,4)triazolo[4,3-b]pyridazin-6-yl oxy)methyl)-2,4-dimethyl-3,4-dihydro-2H-1,4-benzoazoxan-7-yl(3,5-difluorobenzyl)(amino)-2-oxoacetate (14c).** White powder, yield 2.7 g (56%); mp 71-73 °C; \(^1\)H NMR (400 MHz, DMSO-d_6): δ 0.81 (t, J 7.1 Hz, 3H, CH_2CH_3), 1.40 (s, 3H, 2-CH_3), 2.86 (s, 3H, N-CH_3), 3.10 (d, J 11.9 Hz, 1H, 3-H), 3.35 (d, overlapped with water, 1H, 3-H), 3.94 (q, J 7.1 Hz, 2H, CH_2CH_3), 4.29 (d, J 11.1 Hz, 1H, CH_2O), 4.34 (d, J 11.1 Hz, 1H, CH_2O), 4.88 (s, 2H, Ph-CH_2), 6.58-6.64 (m, 2H, Ar-H^5, Ar-H^6), 6.70 (d, J 8.4 Hz, 1H, Ar-H^6), 6.86-6.92 (m, 2H, Ph), 7.13 (d, J 9.9 Hz, 1H, Ar-H^7), 7.12-7.19 (m, 1H, Ph), 8.30 (dd, J 9.9, 8.0 Hz, 1H, Ar-H^8), 9.43 (d, J 0.7 Hz, 1H, Ar-H^3); \(^13\)C NMR (DMSO-d_6): δ 162.4, 161.8, 160.4, 142.5, 142.0, 139.0, 135.3, 128.7, 126.6, 120.4, 116.6, 114.5, 111.9, 111.0, 110.9, 110.8, 74.0, 69.8, 64.9, 61.2, 53.3, 50.1, 38.0, 20.5, 15.2, 13.3; HRMS (ESI) m/z calcld for C_{27}H_{27}F_{2}N_{6}O_{5} [M + H]^+ 553.2101, found 553.2036; IR (KBr) ν_{max}/cm\(^{-1}\): 3445, 2980, 1733, 1653, 1510, 1300, 1189, 1025, 818; HPLC: 97.1 %, t = 16.5 min. Anal. Calcd. for C_{27}H_{28}F_{2}N_{6}O_{5} × 1/3 H_2O: C, 58.09; H, 4.75; N, 14.90. Found: C, 58.06; H, 4.81; N, 15.05%.

**Ethyl 2-(benzyl(2,4-dimethyl-2-((3-methyl[1,2,4]triazolo[4,3-b]pyridazin-6-yloxy)methyl) -3,4-dihydro-2H-1,4-benzoazoxan-7-yl)(amino)-2-oxoacetate (15a).** White powder, yield 2.9 g (60%); mp 75-77 °C; \(^1\)H NMR (400 MHz, DMSO-d_6): δ 0.84 (t, J 7.1 Hz, 3H, CH_2CH_3), 1.38 (s, 3H, 2-CH_3), 2.57 (s, 3H, 3'-CH_3), 2.84 (s, 3H, N-CH_3), 3.09 (d, J 11.9 Hz, 1H, 3-H), 3.33 (d, overlapped with water, 1H, 3-H), 3.95 (q, J 7.1 Hz, 2H, CH_2CH_3), 4.36 (d, J 11.1 Hz, 1H, CH_2O), 4.33 (d, J 11.0 Hz, 1H, CH_2O), 4.84 (s, 2H, Ph-CH_2), 6.52-6.60 (m, 2H, Ar-H^5, Ar-H^6), 6.68 (d, J 8.5 Hz, 1H, Ar-H^8), 7.05 (d, J 9.8 Hz, 1H, Ar-H^7), 7.12-7.37 (m, 5H, Ph), 8.22 (d, J 9.8 Hz, 1H, Ar-H^8); \(^13\)C NMR (DMSO-d_6): δ 162.6, 161.7, 159.9, 146.0, 142.7, 141.9, 136.3, 135.2, 129.0, 128.5, 127.8, 127.4, 126.7, 120.5, 115.5, 114.7, 111.9, 74.1, 69.5, 61.0, 53.2, 50.8, 38.1, 20.7, 13.3, 9.2 (two more peaks overlapped with DMSO); HRMS (ESI) m/z calcld for C_{28}H_{31}N_{6}O_{5} [M + H]^+ 531.2356, found 531.2345; IR (KBr) ν_{max}/cm\(^{-1}\): 3435, 2980, 1741, 1664,
1518, 1334, 1193, 1021, 816; HPLC: 100%, t<sub>r</sub> 16.0 min; Anal. Calcd. for C<sub>28</sub>H<sub>30</sub>N<sub>6</sub>O<sub>5</sub>: C, 63.06; H, 5.70; N, 15.60. Found: C, 63.38; H, 5.70; N, 15.84%.

**Ethyl 2-((2,4-dimethyl-2-(((3-methyl-[1,2,4]triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-3,4-dihydro-2H-1,4-benzoxazin-7-yl)(4-fluorobenzyl)amino)-2-oxoacetate (15b)**. White powder, yield 2.5 g (51%); mp 74-76 °C; ¹H NMR (400 MHz, DMSO-d<sub>6</sub>): δ 0.83 (t, J 7.1 Hz, 3H, CH<sub>2</sub>CH<sub>3</sub>), 1.39 (s, 3H, 2-CH<sub>3</sub>), 2.57 (s, 3H, 3'-CH<sub>3</sub>), 2.85 (s, 3H, N-CH<sub>3</sub>), 3.10 (d, J 11.9 Hz, 1H, 3-H), 3.33 (d, overlapped with water, 1H, 3-H) 3.94 (q, J 7.1 Hz, 2H, CH<sub>2</sub>CH<sub>3</sub>), 4.37 (d, J 11.0 Hz, 1H, CH<sub>2</sub>O), 4.33 (d, J 11.0 Hz, 1H, CH<sub>2</sub>O), 4.83 (s, 2H, Ph-CH<sub>2</sub>), 6.52-6.57 (m, 2H, Ar-H<sup>5</sup>, Ar-H<sup>6</sup>), 6.68 (d, J 9.2 Hz, 1H, Ar-H<sup>8</sup>), 7.05 (d, J 9.8 Hz, 1H, Ar-H<sup>7</sup>), 7.11-7.24 (m, 4H, Ph), 8.23 (d, J 9.8 Hz, 1H, Ar-H<sup>8</sup>); <sup>13</sup>C NMR (DMSO-d<sub>6</sub>): δ 162.6, 161.7, 160.0, 146.0, 142.7, 141.9, 135.3, 132.6, 132.5, 130.0, 129.9, 128.8, 126.7, 120.6, 115.5, 115.4, 115.2, 114.8, 111.9, 74.1, 69.5, 61.0, 53.2, 50.0, 38.0, 20.7, 13.3, 9.2; HRMS (ESI) m/z calcd for C<sub>28</sub>H<sub>30</sub>N<sub>6</sub>O<sub>5</sub>[M + H]<sup>+</sup> 549.2262, found 549.2270; IR (KBr) v<sub>max/cm</sub><sup>−1</sup>: 3422, 3071, 2981, 1741, 1664, 1511, 1194, 1021, 816; HPLC: 100%, t<sub>r</sub> 16.0 min. Anal. Calcd. for C<sub>28</sub>H<sub>29</sub>N<sub>6</sub>O<sub>5</sub> × ½ H<sub>2</sub>O: C, 60.48; H, 5.35; N, 15.01. Found: C, 60.31; H, 5.42; N, 15.07%.

**Ethyl 2-((3,5-difluorobenzyl)(2,4-dimethyl-2-(((3-methyl-[1,2,4]triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-3,4-dihydro-2H-1,4-benzoxazin-7-yl)amino)-2-oxoacetate (15c)**. White powder, yield 2.9 g (59%); mp 77-79 °C; ¹H NMR (400 MHz, DMSO-d<sub>6</sub>): δ 0.85 (t, J 7.1 Hz, 3H, CH<sub>2</sub>CH<sub>3</sub>), 1.40 (s, 3H, 2-CH<sub>3</sub>), 2.57 (s, 3H, 3'-CH<sub>3</sub>), 2.86 (s, 3H, N-CH<sub>3</sub>), 3.10 (d, J 11.9 Hz, 1H, 3-H), 3.32-3.35 (d, overlapped with water, 1H, 3-H), 3.97 (q, J 7.1 Hz, 2H, CH<sub>2</sub>CH<sub>3</sub>), 4.34 (d, J 11.0 Hz, 1H, CH<sub>2</sub>O), 4.38 (d, J 11.1 Hz, 1H, CH<sub>2</sub>O), 4.87 (s, 2H, Ph-CH<sub>2</sub>), 6.59-6.64 (m, 2H, Ar-H<sup>5</sup>, Ar-H<sup>6</sup>), 6.66-6.73 (m, 1H, Ar-H<sup>8</sup>), 6.90 (d, J 6.2 Hz, 2H, Ph), 7.05 (d, J 9.8 Hz, 1H, Ar-H<sup>7</sup>), 7.11-7.18 (m, 1H, Ph), 8.22 (d, J 9.8 Hz, 1H, Ar-H<sup>8</sup>); <sup>13</sup>C NMR (DMSO-d<sub>6</sub>): δ 162.4, 161.8, 160.0, 146.0, 142.1, 135.4, 128.7, 126.7, 120.4, 115.4, 114.5, 111.9, 111.0, 110.9, 110.8, 110.7, 103.3, 103.0, 102.8, 74.1, 69.5, 61.1, 53.2, 50.2, 38.1, 20.7, 13.3, 9.2; HRMS (ESI) m/z calcd for C<sub>28</sub>H<sub>29</sub>F<sub>2</sub>N<sub>6</sub>O<sub>5</sub>[M + H]<sup>+</sup> 567.2167, found 567.2173; IR (KBr) v<sub>max/cm</sub><sup>−1</sup>: 3422, 3078, 2981, 1743, 1667, 1518, 1301, 1200, 1029, 815; HPLC: 98.5%, t<sub>r</sub> 16.9 min. Anal. Calcd. for C<sub>28</sub>H<sub>28</sub>F<sub>2</sub>N<sub>6</sub>O<sub>5</sub>: C, 59.23; H, 5.06; N, 14.61. Found: C, 59.36; H, 4.98; N, 14.83%.

**General procedure for alkaline hydrolysis of ethyl esters (14a-c) and (15a-c)**

To the solution of ester 14a (1 g, 1.94 mmol) in tetrahydrofuran (6 mL) and methanol (2 mL), 1M LiOH (11.6 ml, 11.6 mmol) was added and the reaction mixture stirred at room temperature for 2 hours. Solvent was evaporated under vacuum and the resulting aqueous solution neutralized with 1M hydrochloric acid until the product started to precipitate. The product was filtered to obtain 16a as a pale purple powder (521 mg, yield 55%).

**2-((2-((1,2,4)Triazolo[4,3-b]pyridazin-6-yl)oxy)methyl)-2,4-dimethyl-3,4-dihydro-2H-1,4-benzoxazin-7-yl)(benzyl)amino)-2-oxoacetic acid (16a)**. Pale purple powder, yield 521 mg (55%); mp 130-132 °C; ¹H NMR (400 MHz, DMSO-d<sub>6</sub>): δ 1.39 (s, 3H, 2-CH<sub>3</sub>), 2.84 (s, 3H, N-CH<sub>3</sub>), 3.08 (d, J 11.8 Hz, 1H, 3-H), 3.29-3.35 (d, overlapped with water, 1H, 3-H), 4.30 (d, J 11.0 Hz, 1H, CH<sub>2</sub>O), 4.35 (d, J 11.0 Hz, 1H, CH<sub>2</sub>O), 4.82 (d, J 2.9 Hz, 2H, Ph-CH<sub>2</sub>), 6.57-6.63
(m, 2H, Ar-H), 6.64-6.69 (m, 1H, Ar-H), 7.12 (d, J 9.8 Hz, 1H, Ar-H), 7.15-7.35 (m, 5H, Ph), 8.30 (dd, J 9.8, 0.8 Hz, 1H, Ar-H), 9.41 (d, J 0.8 Hz, 1H, Ar-H); \( ^{13} \)C NMR (DMSO-d6): \( \delta \) 164.3, 163.2, 160.4, 142.5, 141.9, 138.9, 136.6, 135.0, 129.6, 128.4, 127.7, 127.2, 126.5, 120.5, 116.6, 114.6, 111.8, 74.1, 69.9, 61.1, 53.3, 50.7, 38.0, 20.7, 13.3; HRMS (ESI) \( m/z \) ccalc for C25H23N6O5 [M + H]+ 503.1598, found 503.1594; IR (KBr) \( \nu \) max/cm\(^{-1}\): 3432, 3085, 2938, 1734, 1655, 1518, 1300, 1218, 1021, 821; HPLC: 92.0%, tR 12.6 min.

2-((2,4-Dimethyl-2-((3-methyl-[1,2,4]triazolo[4,3-b]pyridazin-6-yloxy)methyl)-3,4-dihydro-2H-1,4-benzoazin-7-yl)(4-fluorobenzyl)amino)-2-oxoacetic acid (17b). Pale purple powder,
yield 474 mg (50%); mp 129-131 °C; ¹H NMR (400 MHz, DMSO-d₆): δ 1.36 (s, 3H, 2-CH₃), 2.54 (s, 3H, 3'-CH₃), 2.79 (s, 3H, N-CH₃), 3.00 (d, J 11.7 Hz, 1H, 3-H), 3.26 (d, J 11.7 Hz, 1H, 3-H), 4.34 (s, 2H, CH₂O), 4.70 (d, J 2.9 Hz, 2H, Ph-CH₂), 6.25-6.73 (m, 3H, Ar-H⁵, Ar-H⁶, Ar-H⁸), 6.97-7.23 (m, 5H, Ph, Ar-H⁷), 8.18 (d, J 9.8 Hz, 1H, Ar-H⁸); ¹³C NMR (DMSO-d₆): δ 162.1, 160.7, 146.8, 142.6, 135.0, 134.4, 130.8, 129.9, 128.6, 127.3, 120.3, 116.2, 115.7, 115.5, 114.6, 112.6, 111.2, 74.9, 70.5, 54.3, 50.2, 38.9, 21.7, 13.2, 9.9; HRMS (ESI) m/z calcd for C₂₆H₂₆FN₆O₅ [M + H]⁺ 521.1949, found 521.1931; IR (KBr) ν/cm⁻¹: 3346, 2936, 1742, 1649, 1503, 1303, 1126, 1022, 820; HPLC: 95.9%, tᵣ 13.7 min.

2-((3,5-Difluorobenzyl)(2,4-dimethyl-2-(((3-methyl-[1,2,4]triazolo[4,3-b]pyridazin-6-yl)-oxy)methyl)-3,4-dihydro-2H-1,4-benzoazin-7-yl)amino)-2-oxoacetic acid (17c). Pale purple powder, yield 409 mg (43%); mp 128-130 °C; ¹H NMR (400 MHz, DMSO-d₆): δ 1.39 (s, 3H, 2-CH₃), 2.56 (s, 3H, 3'-CH₃), 2.85 (s, 3H, N-CH₃), 3.10 (d, J 11.9 Hz, 1H, 3-H), 3.34 (d, J 11.9 Hz, 1H, 3-H), 4.37 (s, 2H, CH₂O), 4.83 (s, 2H, Ph-CH₂), 6.60-6.65 (m, 2H, Ar-H⁵, Ar-H⁶), 6.69 (d, J 8.5 Hz, 1H, Ar-H⁸), 6.86-6.92 (m, 2H, Ph), 7.04 (d, J 9.8 Hz, 1H, Ar-H⁷), 7.07-7.15 (m, 1H, Ph), 8.21 (d, J 9.8 Hz, 1H, Ar-H⁸); ¹³C NMR (DMSO-d₆): δ 164.1, 163.6, 163.4, 160.0, 142.8, 142.1, 141.3, 135.2, 129.4, 126.7, 120.3, 115.5, 114.6, 112.0, 110.9, 110.6, 102.8, 74.2, 69.7, 61.0, 53.2, 50.0, 38.1, 20.8, 13.1, 9.2; HRMS (ESI) m/z calcd for C₂₆H₂₆F₂N₆O₅ [M + H]⁺ 539.1854, found 539.1828; IR (KBr) ν/cm⁻¹: 3422, 2937, 2488, 1734, 1656, 1519, 1303, 1118, 822; HPLC: 93.3%, tᵣ 14.1 min.

Cell cultures

Bovine aortic endothelial cells (BAEC) were kindly provided by Prof. M. Presta (Brescia, Italy). Human cervical carcinoma (HELA) and human breast carcinoma (MCF-7) cells were obtained from the American Type Culture Collection (ATCC, Middlesex, UK). The cells were grown in Dulbecco’s modified minimum essential medium (DMEM, Life Technologies, Inc., Rockville, MD) supplemented with 10 mM Hepes (Life Technologies, Inc., Rockville, MD) and 10% fetal bovine serum (FBS, Harlan Sera-Lab Ltd., Loughborough, UK). Human microvascular endothelial cells (HMEC-1) were obtained from the Centers of Disease Control (CDC, Atlanta, GA) and grown in EGM-2 medium with supplements and growth factors (Lonza, Verviers, Belgium).

Cell proliferation assays

Cells (HMEC-1, BAEC, HELA or MCF-7) were seeded in 48-well plates at 10,000 cells per cm². After 16 h, the cells were incubated in fresh medium in the presence of the test compounds, as indicated in the Results section. On day 4, (BAEC, HELA, MCF-7) or day 7 (HMEC-1) cells were trypsinized and counted by a Coulter counter (Analis, Belgium).
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