SYNTHESIS AND SELECTED TRANSFORMATIONS OF 3-OXIDO-1*H*-IMIDAZOLE-4-CARBOXAMIDES

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An efficient synthesis of new *N*-alkyl- and *N*-aryl-3-oxido-1*H*-imidazole-4-carboxamides based on exploration of inexpensive, commercially available ethyl acetoacetate, paraformaldehyde and primary amines is described. Representative compounds were tested in selected transformations, such as 'sulfur-transfer reaction' leading to imidazole-2-thiones and isomerization to corresponding imidazol-2-ones. Strong intramolecular hydrogen bonding via the *N*-oxide function results in the reduced reactivity of 3-oxido-1*H*-imidazole-4-carboxamides in both reactions. Moreover, the palladium catalyzed C(2)-arylation of imidazole ring as well as azide-alkyne [3+2] cycloaddition using the *N*-propargyl substituted 4-carboxamide derived from an imidazole 3-oxide as a dipolarophile, were also studied.
Keywords: Imidazole *N*-oxides; Carboxamides; Hydrogen bond; 1,3-Dipolar cycloaddition; Direct arylation.

1*H*-Imidazole *N*-oxides are recognized as easily accessible and useful building blocks in the modern organic chemistry[1], including synthesis of biologically active compounds[2]. Special attention is focused on 2-unsubstituted derivatives, which react with electron-deficient dipolarophiles analogously to aldonitrons, yielding diversely functionalized imidazoles via initially formed, unstable [3+2] cycloadducts[3]. However, in many cases, 2-unsubstituted imidazole *N*-oxides are described as reactive compounds and upon heating, the UV irradiation or in the presence of an acylating agent, smoothly undergo isomerization to yield the corresponding imidazol-2-ones[4]. On the other hand, some derivatives, e.g. imidazole *N*-oxides bearing alkylcarboxylic moiety attached to N(1) atom, are stable even in boiling toluene[5]. In this case, the enhanced stability of the *N*-oxide form is explained by 'the association between the *N*-oxide and COOH group'. However, extremely poor solubility of these products in common organic

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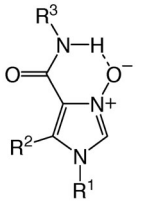
solvents limits significantly their usefulness for standard synthetic methodologies.

Amides of type **2**, derived from imidazole-4-carboxylic acid are known and their remarkable stability was explained by the fact of an intramolecular hydrogen bonding between N→O function and the N-H amide group located at C(4) (Fig. 1; R^1 = alkyl or aryl, R^2 = Me)[6]. More recently, we described the synthesis and crystal-structure determination of *N*-cyclopropyl-1,5-dimethyl-3-oxido-1*H*-imidazole-4-carboxamide (derivative of type **1**), which proved that expectation (Fig. 1; R^1 = R^2 = Me, R^3 = *c*Prop)[7].

In the present paper, a general method for the preparation of the H-bonded 1-alkyl-3-oxido-1*H*-imidazole-4-carboxamides **1** supplemented by some novel 1-aryl analogues **2** is described. In addition, some aspects related to the reactivities of *N*-oxides **1** and **2**, relevant for their applications in the synthesis of new imidazole derivatives, are studied.



1 R^3 = Alkyl
2 R^3 = Aryl

FIG. 1
3-Oxido-1*H*-imidazole-4-carboxamides **1** and **2**

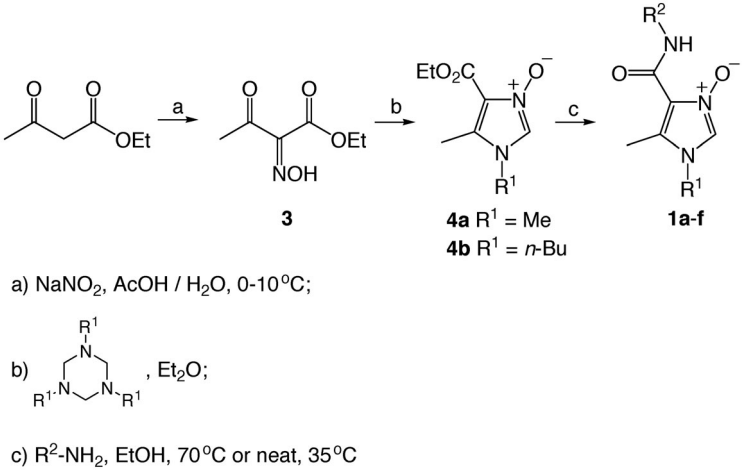
RESULTS AND DISCUSSION

For the present study, easily accessible ethyl acetoacetate, paraformaldehyde, alkylamines, aniline or its *p*-substituted derivatives were applied as starting materials for the synthesis of imidazole *N*-oxides **1** and **2**, respectively. The *N*-alkyl secondary amides **1** were prepared by aminolysis of corresponding ethyl esters **4** (Scheme 1). The initial experiment was carried out using **4a** and excess of methylamine (as ethanolic solution). In this case the reaction solution was heated at 70 °C and after ca. 30 min. precipitation of a colorless solid was observed. After 4 h heating reaction was complete and product **1a** was isolated in 77% yield. The same protocol was applied for **4b** and methylamine yielding **1b** in 57% yield. The reactions of **4a** with cyclohexylamine and aminoethanol, were carried out analogously and products **1c** and **1f**, respectively, were obtained. However, in the cases of

allylamine and propargylamine, after 8 h heating, in both cases, conversion was established below 10%, only. Therefore, both reactions were carried out in neat using five- or six-fold excess of the corresponding alkylamine and under that conditions, target products **1d** and **1e** were obtained in 81 and 59% yields, respectively. However, in the case of aniline, no expected product was formed in the raction with **4a** even after 6 h refluxing in EtOH. Similarly, in the cases of sterically hindered alkylamines, such as 1-aminoadamantane and (*R*)-(+)-phenylethylamine, no expected amides, derived from imidazole *N*-oxides **1** were formed. Products **1a–1f** were isolated in satisfactory to good yields as high melting points, colorless solids, which were fully characterized by spectroscopic and analytical data (Table I). In

TABLE I
N-Alkyl-3-oxido-1*H*-imidazole-4-carboxamides **1**

1	R^1	R^2	Yield, %	M.p., °C
a	Me	Me	77	229–231
b	*n*-Bu	Me	57	146–149
c	Me	*c*Hex	54	230–233
d	Me	allyl	81	132–134
e	Me	propargyl	59	245–249
f	Me	2-hydroxyethyl	59	207–212



SCHEME 1
Synthesis of *N*-alkyl- and *N*-cycloalkyl-3-oxido-1*H*-imidazole-4-carboxamides **1a–1f**

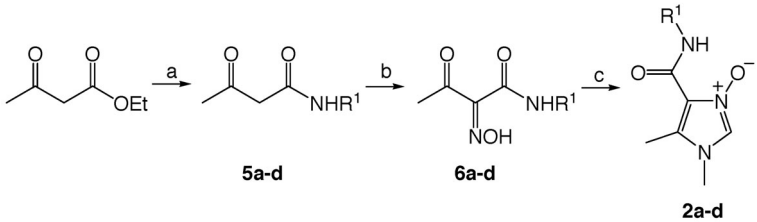
the ^{1}H NMR spectra, the expected diagnostic signals of C(2)-H were found in the region 7.83–8.99 ppm. On the other hand, a broad signal of the -CONH- was located at ca. 10.50 ppm, and in the case of **1a** and **1c**, the coupling constants $^3J_{H,H}$ = 5.6 and 7.2 Hz, respectively, were observed. Strong absorption bands located in the IR spectra of **1a–1f** at ~1650 cm^{-1} proved the presence of the amide function.

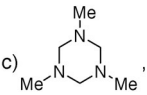
Syntheses of *N*-oxides **4a** (R^1 = Me) and **4b** (R^1 = *n*-Bu) were performed using ethyl α-hydroxyimino-β-oxobutyrate (**3**) and 1,3,5-trisubstituted hexahydro-1,3,5-triazines (trimeric form of the corresponding *N*-alkyl formaldimines) in Et_2O solutions at room temperature (Scheme 1). However, - under these conditions, products **4** co-precipitated with **3** as colorless solids, and after filtration, both compounds were separated chromatographically. In the case of **4a**, the reaction was repeated twice using recovered **3**. Combined fractions were recrystalized to give the expected products in fair yields (60–70%). Alternatively, **4a** and **4b** were prepared in accordance with literature protocol using glacial acetic acid as a solvent[7,8]. In this case, crude products were converted in the corresponding hydrochlorides by passing gaseous HCl through the reaction solutions and in the next step free *N*-oxides **4** were isolated from MeOH–$CHCl_3$ (1:3) solutions after neutralization with solid sodium bicarbonate. In contrast to amides **1**, esters **4** easily undergo isomerization to yield corresponding imidazol-2-ones, even at low temperature (0–5 °C). Therefore, they were used with no storage for the aminolysis step. Starting compound **3** was obtained in multigram scale, following a literature protocol[9].

The *N*-aryl secondary amides of type **2** were obtained from the corresponding α-hydroxyimino-β-oxobutyramides **6** by condensation with (*N*-methylidene)methylamine in boiling EtOH (Scheme 2, Table II)[6]. All products were isolated as high-melting points, crystalline materials in good yields.

TABLE II
N-Aryl-3-oxido-1*H*-imidazole-4-carboxamides **2**

2	R^1	Yield, %	M.p., °C
a	Ph	79	208–210
b	*p*-C_6H_5Br	83	245–250
c	*p*-C_6H_5F	70	263–269
d	*p*-$C_6H_5BrNO_2$	80	271–277

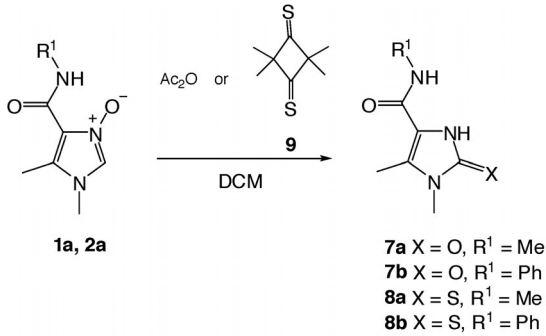


a) R^1-NH_2, MW irradiation or boiling xylenes;
b) $NaNO_2/H_2O$, glacial AcOH, 5 °C;
c)  , EtOH, reflux 3 h

SCHEME 2
Synthesis of *N*-aryl-3-oxido-1*H*-imidazole-4-carboxamides **2a**–**2d**

Compounds **6** were prepared from β-oxoamides **5** at 0–5 °C using aqueous solution of $NaNO_2$ in glacial acetic acid. Amides **5** are accesible by two different methods starting with ethyl acetoacetate and aniline or its *p*-substituted derivatives. In the case of **5a** and **5b** irradiation of the corresponding mixture of substrates in commercial microwave oven at 600 Watt for 3–6 min turned out as a method of choice (94 and 78% yield, respectively)[10]. However, attempted synthesis of **5c** or **5d** using this method failed, and the expected products were isolated in very low yields (<5%), only. Alternatively, required products were prepared by refluxing the corresponding anilines with 50% excess of ethyl acetoacetate in dry xylenes.

Imidazole *N*-oxides of type **1** and **2**, respectively were used for reactions leading to urea- and thiourea-type imidazole derivatives (compounds **7** and **8**, respectively) (Scheme 3). Since, neither compound **1** nor **2** isomerizes upon heating in toluene, required imidazol-2-ones **7a** and **7b**, respectively, were obtained by treatment of the corresponding *N*-oxides with excess of Ac_2O in dry CH_2Cl_2 at room temperature. Typically, 1,4,5-trisubstituted imidazole *N*-oxides undergo complete conversion within ca. 2 h at room temperature[4a]. However, in the cases of **1a** and **2b**, rearrangement of the starting material under the same conditions was observed after 12 h (TLC monitoring). Diminished reactivity of imidazole *N*-oxides **1** was also observed in the 'sulfur-transfer reaction'[3a]. The imidazole-2-thiones **8a**–**8b**, expected in the reactions of **1a** and **2a** with 2,2,4,4-tetramethylcyclobutane-1,3-dithione (**9**), were formed after 16 h, only. This is worth of noting, that a typical conversion of an 2-unsubstituted imidazole *N*-oxide into the corresponding imidazole-2-thione was reported to take approximately 30 min[3a].



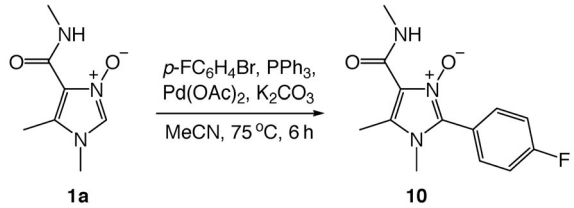
SCHEME 3
Transformations of imidazole *N*-oxides **1a** and **2a** into corresponding imidazol-2-ones **7a–7b** and imidazole-2-thiones **8a–8b**

Structures of imidazol-2-ones **7a–7b** and imidazole-2-thiones **8a–8b** were proved by means of IR, NMR and HRMS data. For instance, the ^{1}H NMR spectrum of **7a** (DMSO-d_6) showed two NH signals registered as a singlet at 9.96 ppm and a broad doublet at 7.34 ppm, respectively. In the same spectrum, three signals assigned to Me groups were found at 2.32, 3.06 (2 s) and 2.69 ppm (d, $^3J_{H,H}$ = 4.6 Hz), respectively. On the other hand, the ^{1}H NMR spectrum of the same compound, recorded in CD_3OD, revealed no signal which could be attributed to the NH group and only three singlets of Me groups were observed. Additionally, two broad absorptions at 1693 (vs) and 1645 (m) cm^{-1} in the IR spectrum, as well as two singlets of C_q atoms located at 160.3 and 152.2 ppm in the ^{13}C NMR spectrum, confirm the presence of two carbonyl groups.

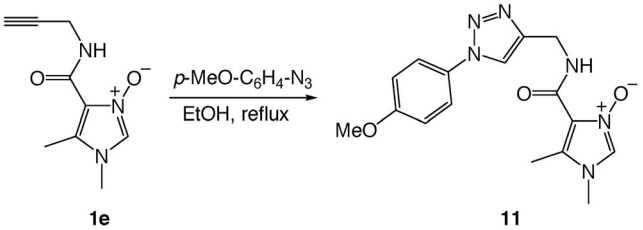
Unexpectedly, in contrast to already reported 2-unsubstituted imidazole *N*-oxides[4a], analogous **1a** and **2a** do not react with cyanotrimethylsilane (Me_3SiCN, 3 equiv. in the presence of freshly dried molecular sieves 4Å) even after 5 days at room temperature (CH_3CN–$CHCl_3$ solution).

In a very recent paper, excellent method for palladium catalyzed direct arylation of α-unsubstituted azaaromatic *N*-oxides was reported[2c]. Following this procedure, the mixture of equimolar amount of **1a** and *p*-bromofluorobenzene was heated in MeCN solution in the presence of Ph_3P, K_2CO_3 and $Pd(OAc)_2$ (Scheme 4). The C(2)-cross-coupled imidazole *N*-oxide **10** was isolated as the only product in 70% yield.

Based on the general concept of [2+3] cycloaddition, the *N*-propargyl derivative **1e** is expected to act as a suitable dipolarophile in the azide-alkyne 'click reaction' catalyzed by Cu(I) salts (stepwise 'Huisgen cycloaddition') (Scheme 5)[11a]. However, imidazole *N*-oxides are known to undergo



SCHEME 4
Direct arylation of imidazole *N*-oxide **1a** with 1-bromo-4-fluorobenzene



SCHEME 5
[3+2] Dipolar cycloaddition of *N*-propargyl-1,5-dimethyl-3-oxido-1*H*-imidazole-4-carboxamide (**1e**) with anisyl azide

smoothly deoxygenation in the presence of Cu(I) salts[11b]. Therefore, no Cu(I) salts can be used to promote the 'click reaction' of the *N*-oxide **1e** with an organic azide. Thus, the EtOH solution containing **1e** and a large excess of 1-azido-4-methoxybenzene was refluxed for 80 h. The target 1,2,3-triazole **11** was isolated chromatographically in 67% yield. Its ^{1}H NMR spectrum reveales two singlets located at 8.66 and 8.60 ppm, respectively. The elemental analysis confirmed the formula $C_{16}H_{18}N_6O_3$.

In summary, studies presented in this paper show that the condensations of ethyl α-hydroxyimino-β-oxobutanoate (**3**) with corresponding 1,3,5-hexahydrotriazines smoothly lead to 2-unsubstituted imidazole *N*-oxides **4**, bearing the ester group at C(4). Subsequent aminolysis of **4** with aliphatic amines yield a new type of imidazole 4-carboxamides **1** with the preserved N→O function. In the case of **4**, attempted conversion into *N*-aryl substituted derivatives was in vain. Therefore, the corresponding anilides **2** were obtained in a two-step procedure starting with acetylacetamides **5**. In comparison with previously studied 4-aryl or 4-alkyl substituted analogues[3,4], imidazole *N*-oxides **1** and **2** are less reactive towards acetic anhydride (isomerization to imidazole-2-one) and 2,2,4,4-tetramethylcyclobutane-

1,3-dithione (sulfur transfer reaction). Moreover, they do not react with cyanotrimethylsilane under typical conditions applied for the 2-cyanation of imidazole *N*-oxides[4a]. Reduced reactivity of **1** and **2** is explained by the presence of a strong intramolecular hydrogen bonding which diminishes nucleophilicity (and basicity) of the N→O functional group. 2-Unsubstituted imidazole *N*-oxides of type **1** can be easily arylated at C(2) using the 'direct arylation' procedure. In the case of the *N*-propargyl substituted derivative **1e**, the corresponding 1,2,3-triazole **11** was obtained as the product of a thermal [2+3] dipolar cycloadditon with *p*-methoxyphenyl azide. In both cases the N→O function is preserved in the molecules of the obtained products.

Presented results show that 4-carboxamide substituted imidazole *N*-oxides **1** and **2** are versatile starting materials for synthesis of highly functionalized imidazole derivatives and poliheterocyclic systems as well.

EXPERIMENTAL

General

Melting points were determined on a Melt-Temp. II apparatus (Aldrich) and are uncorrected. The IR spectra were recorded on a NEXUS FT-IR spectrophotometer in KBr (ν, cm^{-1}). The ^1H and ^{13}C NMR spectra were measured on a Tesla BS567A (80 MHz), Varian Gemini 200 (200 and 50 MHz) or Bruker AC 400 (400 and 100 MHz) instruments using $CDCl_3$, CD_3OD or DMSO-d_6 as solvents. Chemical shifts (δ scale) are given in ppm (TMS = 0 ppm) and coupling constants *J* in Hz. The multiplicity of the ^{13}C signals was deduced from DEPT spectra. The HRMS spectra were measured on a Finnigan MAT-95 instrument.

Starting Materials

Applied reagents such as ethyl acetoacetate, alkylamines, anilines, paraformaldehyde, diethyl maleate, trimethylsilylcyanide and solvents are commercially available (Aldrich) and were used as received. 1,3,5-Trialkylhexahydro-1,3,5-triazines were prepared from the corresponding alkylamines and formaldehyde according to literature protocol[12]. 2,2,4,4-Tetramethylcyclobutane-1,3-dithione[13] and 1-azido-4-methoxybenzene[14] were obtained following known protocols. Ethyl α-hydroxyimino-β-oxobutanoate was obtained by nitrosation of ethyl acetoacetate according to the published protocol[9].

Synthesis of *N*-Alkyl-1,5-dimethyl-3-oxido-1*H*-imidazole-4-carboxamides **1a–1f**

A mixture of imidazole *N*-oxide of type **4** (10 mmol) and corresponding amine (22 mmol) in EtOH (10 ml) was heated at 70 °C (4–12 h, TLC monitoring: SiO_2, AcOEt 1:4 MeOH). Then, the solvent was removed under reduced pressure, crude product was washed with Et_2O and recrystallized.

Products **1d** and **1e** were prepared by heating **4a** with excess (6 eq.) of corresponding amine at 35 °C without solvent (neat) for 20 h.

N-Methyl-1,5-dimethyl-3-oxido-1H-imidazole-4-carboxamide (**1a**). Yield 1.30 g (77%). Colorless crystals, m.p. 229–231 °C (decomp.) (EtOH). IR (KBr): 3121 s, 1647 vs, 1599 vs, 1545 vs, 1457 m, 1409 m, 1373 m, 1324 m, 1285 m, 1162 m, 781 m, 757 m. ^{1}H NMR (80 MHz, $CDCl_3$): 10.49 br. s, 1 H (NH); 7.83 s, 1 H (H-C(2)); 3.58 s, 3 H (NMe, imidazole); 2.94 d, 3 H, *J* = 5.6 (NH**Me**); 2.61 s, 3 H (Me). ^{13}C NMR (50 MHz, $CDCl_3$): 160.3 s (C=O); 131.0, 121.7 2s (C(4), C(5)); 125.9 d (C(2)); 31.9, 24.8, 9.1 3q (3 Me). EI-HRMS: 169.0857 (M^+, $C_7H_{11}N_3O_2^+$; calculated 169.0851).

N-Methyl-1-butyl-5-methyl-3-oxido-1H-imidazole-4-carboxamide (**1b**). Yield 1.20 g (57%). Colorless crystals, m.p. 146–149 °C (CH_2Cl_2–Et_2O). IR (KBr): 3093 m, 3018 m, 2958 m, 2933 m, 1653 vs, 1598 vs, 1564 m, 1469 m, 1419 m, 1370 m, 1287 m, 759 m. ^{1}H NMR (200 MHz, $CDCl_3$): 10.13 br. s, 1 H (NH); 7.84 s, 1 H (H-C(2)); 3.68 t, 2 H, *J* = 7.3 (*n*-Bu); 2.74 d, 3 H, *J* = 5.0 (NH**Me**); 2.41 s, 3 H (Me); 1.60–1.45 m, 2 H (*n*-Bu); 1.21–1.10 m, 2 H (*n*-Bu); 0.75 t, 3 H, *J* = 7.2 (*n*-Bu). ^{13}C NMR (50 MHz, $CDCl_3$): 160.2 s (C=O); 130.2, 122.0 2s (2 arom. C); 125.2 d (C(2)-H); 45.4, 25.1, 19.5 3t (3 -CH_2-, *n*-Bu); 32.0, 13.4, 9.5 3q (3 Me). EI-HRMS: 211.1339 (M^+, $C_{10}H_{17}N_3O_2^+$; calculated 211.1321).

N-Cyclohexyl-1,5-dimethyl-3-oxido-1H-imidazole-4-carboxamide (**1c**). Yield 1.28 g (54%). Colorless crystals, m.p. 230–233 °C (decomp.) (EtOH). IR (KBr): 3088 m, 3027 m, 2931 vs, 2858 m, 1655 vs, 1605 vs, 1560 m, 1450 m, 1416 m, 1378 m, 1290 m, 758 m, 631 m, 602 m. ^{1}H NMR (400 MHz, $CDCl_3$): 10.56 br. d, 1 H, *J* = 7.2 (NH); 7.85 s, 1 H (H-C(2)); 4.01–3.92 m, 1 H (*c*Hex); 3.60 s, 3 H (NMe); 2.62 s, 3 H (Me); 1.95–1.92, 1.76–1.72 2m, 4 H (*c*Hex); 1.60–1.27 m, 6 H (*c*Hex). ^{13}C NMR (100 MHz, $CDCl_3$): 158.7 s (C=O); 130.7, 122.4 2s (2 arom. C); 125.2 d (C(2)); 47.2 d (CH, *c*Hex); 32.8, 25.6, 24.6 3t (5 CH_2, *c*Hex); 32.1 q (NMe); 9.5 q (Me). EI-HRMS: 237.1471 (M^+, $C_{12}H_{19}N_3O_2^+$; calculated 237.1477).

N-Allyl-1,5-dimethyl-3-oxido-1H-imidazole-4-carboxamide (**1d**). Yield 1.60 g (81%). Colorless solid, m.p. 132–134 °C (acetone). IR (KBr): 3114 m, 3089 m, 2988 m, 1657 vs, 1641 s, 1602 vs, 1557 s, 1451 m, 1439 m, 1411 m, 1368 m, 1290 m, 754 m, 629 m, 606 m. ^{1}H NMR (80 MHz, $CDCl_3$): 10.82 br. s, 1 H (NH); 7.78 s, 1 H (H-C(2)); 6.18–5.72 m, 1 H (-CH_2-C**H**=CH_2); 5.40–5.04 m, 2 H (-CH_2-CH=C**H**$_2$); 4.14–3.96 m, 2 H (-C**H**$_2$-CH=CH_2); 3.58 s, 3 H (NMe); 2.62 s, 3 H (Me). ^{13}C NMR (50 MHz, $CDCl_3$): 159.4 s (C=O); 134.1 d (-CH_2-**C**H=CH_2); 131.3, 122.0 2s (2 arom. C); 126.2 d (C(2)); 115.8 t (=CH_2); 40.7 t (-CH_2-); 32.2 q (NMe); 9.4 q (Me). EI-HRMS: 195.1019 (M^+, $C_9H_{13}N_3O_2^+$; calculated 195.1008).

N-Propargyl-1,5-dimethyl-3-oxido-1H-imidazole-4-carboxamide (**1e**). Yield 1.14 g (59%). Colorless crystals, m.p. 245–249 °C (decomp.) (EtOH). IR (KBr): 3214 s, 3112 m, 3042 m, 1652 vs, 1602 s, 1544 s, 1453 m, 1415 m, 1376 m, 1349 m, 1287 m, 739 s, 625 m, 603 m. ^{1}H NMR (200 MHz, $CDCl_3$): 9.72 br. s, 1 H (NH); 8.99 s, 1 H (H-C(2)); 4.20 dd, 2 H, *J* = 5.4, 2.5 (-CH_2-); 3.75 s, 3 H (NMe); 2.63 s, 3 H (Me); 2.25 t, 1 H, *J* = 2.5 (-C≡CH). ^{13}C NMR (50 MHz, $CDCl_3$): 158.3 s (C=O); 132.6, 121.3 2s (2 arom. C); 128.2 d (C(2)); 79.3 s (-**C**≡CH); 71.3 d (-C≡**C**H); 32.8 q (NMe); 28.3 t (-CH_2-); 9.5 q (Me). EI-HRMS: 193.0862 (M^+, $C_9H_{11}N_3O_2^+$; calculated 193.0851).

N-(2-Hydroxyethyl)-1,5-dimethyl-3-oxido-1H-imidazole-4-carboxamide (**1f**). Yield 1.17 g (59%). Colorless crystals, m.p. 207–212 °C (decomp.) (EtOH). IR (KBr): 3163 vs (br.), 3115 s, 1652 vs, 1595 s, 1538 s, 1450 m, 1281 m, 1061 m, 756 m, 623 m, 607 m. ^{1}H NMR (200 MHz, DMSO-d_6): 10.96 br. t, 1 H, *J* = 5.2 (NH); 8.41 s, 1 H (H-C(2)); 4.83 t, 1 H, *J* = 5.0 (OH); 3.56 s, 3 H (NMe); 3.48 t, 2 H, *J* = 5.1 (-CH_2-); 3.33 t, 2 H, *J* = 5.6 (-CH_2-); 2.50 s, 3 H (Me). ^{13}C NMR (50 MHz, DMSO-d_6): 159.5 s (C=O); 130.2, 120.4 2s (2 arom. C); 126.0 d (C(2)); 59.9, 40.3 2t (2 -CH_2-); 31.7 q (NMe); 9.0 q (Me). EI-HRMS: 199.0956 (M^+, $C_8H_{13}N_3O_3^+$; calculated 199.0957).

Synthesis of *N*-Aryl-1,5-dimethyl-3-oxido-1*H*-imidazole-4-carboxamides (**2**)

A mixture of 1,3,5-trimethylhexahydro-1,3,5-triazine (0.55 g, 4.3 mmol) and corresponding α-hydroxyimino-β-oxobutyramide **6** (10 mmol) in ethanol (15 ml) was refluxed for 3 h. The solvent was removed under vacuum, the crude product was washed with Et_2O and recrystallized.

N-Phenyl-1,5-dimethyl-3-oxido-1H-imidazole-4-carboxamide[6] (**2a**). Yield 1.82 g (79%). Colorless crystals, m.p. 208–210 °C (EtOH–H_2O). IR (KBr): 3363 m, 3012 m, 1671 vs, 1612 vs, 1597 vs, 1559 vs, 1504 m, 1491 s, 1445 s, 1411 m, 1376 m, 1313 s, 1273 m, 1150 m, 762 s. ^{1}H NMR (80 MHz, $CDCl_3$): 12.95 br. s, 1 H (NH); 7.86 s, 1 H (H-C(2)); 7.77–7.59 m (2 arom. H); 7.46–6.94 m (3 arom. H); 3.72 s, 3 H (NMe); 2.63 s, 3 H (Me).

N-(p-Bromophenyl)-1,5-dimethyl-3-oxido-1H-imidazole-4-carboxamide (**2b**). Yield 2.57 g (83%). Colorless crystals, m.p. 245–250 °C (decomp.) (EtOH). IR (KBr): 3145 m, 1655 s, 1610 vs, 1592 s, 1555 vs, 1488 s, 1448 m, 1398 m, 1369 m, 1307 s, 1267 m, 1267 m, 1149 m, 1070 m, 824 m, 803 m, 768 m, 606 m. ^{1}H NMR (400 MHz, $CDCl_3$): 12.73 br. s, 1 H (NH); 8.07 s, 1 H (H-C(2)); 7.53 d, J = 8.8 (2 arom. H); 7.41 d, J = 8.8 (2 arom. H); 3.62 s, 3 H (NMe); 2.60 s, 3 H (Me). ^{13}C NMR (100 MHz, $CDCl_3$): 157.9 s (C=O); 137.2, 133.3, 121.6, 117.4 4s (4 arom. C); 132.4, 122.5 2d (4 arom. CH); 127.2 d (C(2), imidazole); 32.8 q (NMe); 9.9 q (Me). EI-HRMS: 309.0109 (M^+, $C_{12}H_{12}BrN_3O_2^+$; calculated 309.0113).

N-(p-Fluorophenyl)-1,5-dimethyl-3-oxido-1H-imidazole-4-carboxamide (**2c**). Yield 1.74 g (70%). Colorless crystals, m.p. 263–269 °C (EtOH). IR (KBr): 3007 m, 3100–2400 m (br.), 1670 s, 1621 vs, 1578 s, 1507 vs, 1449 m, 1411 m, 1377 m, 1316 m, 1216 m, 837 m. ^{1}H NMR (80 MHz, $CDCl_3$): 12.96 br. s, 1 H (NH); 7.85 s, 1 H (H-C(2)); 7.76–7.59 m (2 arom. H); 7.13–6.91 m (2 arom. H); 3.61 s, 3 H (NMe); 2.66 s, 3 H (Me). ^{13}C NMR (50 MHz, $CDCl_3$): 159.2 d, $^1J_{C\text{-}F}$ = 241.8 (1 arom. C); 157.3 s (C=O); 134.0 d, $^4J_{C\text{-}F}$ = 2.8 (1 arom. C); 131.8, 121.8 2s (2 arom. C, imidazole); 125.7 d (C(2), imidazole); 122.0 d, $^3J_{C\text{-}F}$ = 7.8 (2 arom. CH); 115.5 d, $^2J_{C\text{-}F}$ = 22.5 (2 arom. CH); 32.2 q (NMe); 9.5 q (Me). EI-HRMS: 249.0924 (M^+, $C_{12}H_{12}FN_3O_2^+$; calculated 249.0914).

N-(4-Nitrophenyl)-1,5-dimethyl-3-oxido-1H-imidazole-4-carboxamide (**2d**). Yield 2.21 g (80%). Orange solid, m.p. 271–277 °C (decomp.) (EtOH). IR (KBr): 1674 m, 1622 m, 1577 vs, 1500 s, 1448 m, 1405 m, 1375 m, 1327 vs, 1302 s, 1282 s, 1151 m, 1107 m, 853 m, 801 m, 605 m. ^{1}H NMR (200 MHz, DMSO-d_6): 14.27 br. s, 1 H (NH); 8.61 s, 1 H (H-C(2)); 8.23 d, J = 9.2 (2 arom. H); 7.86 d, J = 9.2 (2 arom. H); 3.60 s, 3 H (NMe); 2.55 s, 3 H (Me). ^{13}C NMR (50 MHz, $CDCl_3$): 158.0 s (C=O); 144.2, 142.7, 133.1, 118.9 4s (4 arom. C); 125.2, 119.4 2d (4 arom. CH); 127.5 d (C(2), imidazole); 32.0 q (NMe); 9.2 q (Me). EI-HRMS: 276.0858 (M^+, $C_{12}H_{12}N_4O_4^+$; calculated 276.0858).

Sythesis of Ethyl 3-oxido-1*H*-imidazole-4-carboxylates (**4**)

To the solution of (α-hydroxyimino)ketone **3** (10 mmol) in Et_2O (5 ml), a solution of corresponding 1,3,5-trialkylhexahydro-1,3,5-triazine (0.45 mmol) in Et_2O (2 ml) was added at 0 °C; when the addition was complete, the cooling bath was removed. The mixture was magnetically stirred for 24 h, the colorless precipitate was filtered and flash chromatographed (SiO_2, Me_2CO and then AcOEt–MeOH (1:1) mixture) to give the starting **3** and the crude product **4**. The reaction and purification were repeated twice using recovered **3**. Combined fractions of crude products **4** were recrystallized from the appropriate solvents. Alternatively, the synthesis of **4a** and **4b** was repeated using glacial acetic acid as solvent to give target products in 82 and 61% yield, respectively[7,8].

Ethyl 1,5-dimethyl-3-oxido-1H-imidazole-4-carboxylate[7] (**4a**). Yield 1.23 g (67%). Colorless crystals, m.p. 76–78 °C (CH_2Cl_2–Et_2O). ^{1}H NMR (80 MHz, $CDCl_3$): 8.13 s, 1 H (H-C(2)); 4.34 q, 2 H, *J* = 7.0 (OEt); 3.59 s, 3 H (NMe); 2.47 s, 3 H (Me); 1.39 t, 3 H, *J* = 7.0 (OEt).

Ethyl 1-butyl-5-methyl-3-oxido-1H-imidazole-4-carboxylate (**4b**). Yield 1.31 g (58%). Colorless oil. IR (KBr): 2980–2850 m (br.), 1697 vs, 1610 m, 1453 m, 1320 m, 1183 m, 1076 m, 755 m. ^{1}H NMR (200 MHz, $CDCl_3$): 8.08 s, 1 H (H-C(2)); 4.32 q, 2 H, *J* = 7.1 (OEt); 3.81 t, 2 H, *J* = 7.1 (Bu); 2.40 s, 3 H (Me); 1.78–1.26 m, 4 H (Bu); 1.31 t, 3 H, *J* = 7.1 (OEt); 0.87 t, 3 H, *J* = 7.1 (Bu). ^{13}C NMR (50 MHz, $CDCl_3$): 159.0 s (C=O); 131.7, 121.6 2s (2 arom. C); 126.8 d (C(2)); 60.8 t (OEt); 45.6, 31.8, 19.3 3t (3 CH_2, Bu); 14.0 q (OEt); 13.2 q (CH_3, Bu); 9.9 q (Me). EI-HRMS: 226.1322 (M^+, $C_{11}H_{18}N_2O_3^+$; calculated 226.1317).

Synthesis of Acetoacetanilides (**5**)

Method A (MW induced acetoacetylation of amines): A mixture of ethyl acetoacetate (3 mmol) and corresponding amine (1 mmol) was placed in an Ehrlenmeyer flask equiped with conical adapter containing silica gel. The reaction mixture was irradiated at 600 W in a commercial microwave oven for required time. The resulting residue was washed with petroleum ether and filtered, and the crude product was recrystallized from EtOH.

3-Oxo-N-phenylbutyramide[10] (**5a**): Time 6 min. Yield 166 mg (94%). Colorless crystals, m.p. 79–81 °C (EtOH). IR (KBr): 3288 m, 3254 m, 1725 vs, 1713 vs, 1662 vs, 1600 s, 1541 s, 1498 s, 1446 s, 1409 s, 1362 m, 1341 m, 1314 m, 1167 m, 755 s, 691 s. ^{1}H NMR (80 MHz, $CDCl_3$): 9.05 br. s, 1 H (NH); 7.64–7.07 m (5 arom. H); 3.55 s, 2 H (CH_2); 2.30 s, 3 H (CH_3).

N-(4-Bromophenyl)-3-oxobutyramide[10] (**5b**): Time 3 min. Yield 189 mg (78%). Colorless crystals, m.p. 142–143 °C (EtOH). IR (KBr): 3288 m, 3250 m, 1716 vs, 1659 vs, 1605 s, 1552 s, 1490 s, 1416 m, 1395 m, 1361 m, 1341 m, 1312 m, 1161 m, 1075 m, 832 s, 816 m. ^{1}H NMR (80 MHz, $CDCl_3$): 9.21 br. s, 1 H (NH); 7.43 s (4 arom. H); 3.57 s, 2 H (CH_2); 2.32 s, 3 H (CH_3).

Method B (Thermal condensation): A mixture of ethyl acetoacetate (15 mmol) and corresponding aniline (10 mmol) in dry xylene (25 ml) was placed in a round-bottomed flask, equipped with a Dean–Stark apparatus and heated under reflux for 8 h. The crude mixture was flash chromatographed (SiO_2, petroleum ether, then AcOEt), the solvents were removed, the oily residue was treated with Et_2O, cooled and filtered. The obtained crude solid was purified by recrystallization from appropriate solvent to give analytically pure **5**.

N-(4-Flurophenyl)-3-oxobutyramide (**5c**). Yield 0.21 g (11%). Colorless solid, m.p. 94–96 °C (EtOH). IR (KBr): 3258 m, 3069 m, 1720 s, 1666 vs, 1621 m, 1569 m, 1553 m, 1511 vs, 1414 s, 1215 m, 1167 s, 838 s. ^{1}H NMR (200 MHz, $CDCl_3$): 9.25 br. s, 1 H (NH); 7.49–7.43 m (2 arom. H); 7.00–6.92 m (2 arom. H); 3.53 s, 2 H (CH_2); 2.26 s, 3 H (CH_3). ^{13}C NMR (50 MHz, $CDCl_3$): 205.0 s (C=O); 164.0 s (CONH); 159.5 d, $^1J_{C\text{-}F}$ = 242.5 (1 arom. C); 133.5 d, $^4J_{C\text{-}F}$ = 2.8 (1 arom. C); 122.0 d, $^3J_{C\text{-}F}$ = 7.9 (2 arom. CH); 115.5 d, $^2J_{C\text{-}F}$ = 22.3 (2 arom. CH); 49.8 t (CH_2); 30.9 q (CH_3). EI-HRMS: 195.0713 (M^+, $C_{10}H_{10}FNO_2^+$; calculated 195.0696).

N-(4-Nitrophenyl)-3-oxobutyramide[15] (**5d**). Yield 1.06 g (48%). Light yellow needles, m.p. 151–152 °C (decomp.) (EtOH). IR (KBr): 3303 m, 3271 m, 1717 s, 1668 vs, 1617 m, 1596 m, 1570 vs, 1514 vs, 1419 m, 1411 m, 1336 vs, 1159 m, 1115 m, 857 m, 749 m. ^{1}H NMR (200 MHz, $CDCl_3$): 9.68 br. s, 1 H (NH); 8.20 d, *J* = 8.8 (2 arom. H); 7.73 d, *J* = 8.3 (2 arom. H); 3.64 s, 2 H (CH_2); 2.34 s, 3 H (CH_3).

Synthesis of 2-Hydroxyimino-3-oxobutyramides (**6**)

To the saturated solution of amide **5** (10 mmol) in glacial acetic acid (ca. 5–10 ml) cooled to 5 °C, a solution of $NaNO_2$ (1.0 g, 14 mmol) in H_2O (3 ml) was added dropwise. Then, cooling bath was removed and the resulting mixture was stirred at room temperature for 1 h, diluted with H_2O (ca. 100 ml) and cooled. The obtained portions of precipitate were collected, washed with H_2O, dried and recrystallized.

2-Hydroxyimino-3-oxo-N-phenylbutyramide[16] (**6a**). Yield 1.83 g (89%). Light yellow needles, m.p. 98–100 °C ($CHCl_3$–petroleum ether). IR (KBr): 3250–3000 m (br.), 1680 vs, 1644 m, 1604 s, 1566 s, 1537 vs, 1496 s, 1407 s, 1361 s, 1292 s, 1104 m, 1036 s, 898 m, 769 s. ^{1}H NMR (80 MHz, $CDCl_3$): 17.00 s, 1 H (NOH); 10.48 br. s, 1 H (NH); 7.70–7.18 m (5 arom. H); 2.48 s, 3 H (CH_3).

N-(4-Bromophenyl)-2-hydroxyimino-3-oxobutyramide[17] (**6b**). Yield 1.85 g (65%). Colorless solid, m.p. 204–209 °C (decomp.) (EtOH–benzine). IR (KBr): 3350–3000 m (br.), 3334 vs, 1683 vs, 1659 vs, 1626 m, 1606 s, 1549 vs, 1489 s, 1420 m, 1400 s, 1073 m, 1000 s, 818 m. ^{1}H NMR (80 MHz, CD_3OD): 7.63–7.35 m (4 arom. H); 2.41 s, 3 H (CH_3).

N-(4-Flurophenyl)-2-hydroxyimino-3-oxobutyramide (**6c**). Yield 0.76 g (34%). Colorless needles, m.p. 121–123 °C (petroleum). IR (KBr): 3330 s, 3250–2950 m (br.), 1686 vs, 1656 vs, 1621 s, 1565 s, 1509 s, 1424 m, 1412 s, 1366 m, 1296 m, 1230 m, 1080 m, 1001 vs, 825 s. ^{1}H NMR (200 MHz, $CDCl_3$): 16.94 s, 1 H (NOH); 10.97 br. s, 1 H (NH); 7.60–7.53 m (2 arom. H); 7.07–7.03 m (2 arom. H); 2.57 s, 3 H (CH_3). ^{13}C NMR (50 MHz, $CDCl_3$): 200.3 s (C=O); 161.3 s (CONH); 160.5 d, $^1J_{C\text{-}F}$ = 245.6 (1 arom. C); 143.4 s (C=N); 131.4 d, $^4J_{C\text{-}F}$ = 2.8 (1 arom. C); 123.1 d, $^3J_{C\text{-}F}$ = 7.9 (2 arom. CH); 116.1 d, $^2J_{C\text{-}F}$ = 22.6 (2 arom. CH); 26.2 q (CH_3). EI-HRMS: 224.0601 (M^+, $C_{10}H_9FN_2O_3^+$; calculated 224.0597).

2-Hydroxyimino-N-(4-nitrophenyl)-3-oxobutyramide[18] (**6d**). Yield 1.48 g (59%). Light yellow crystals, m.p. 179–182 °C (H_2O). ^{1}H NMR (80 MHz, $CDCl_3$): 16.72 br. s, 1 H (NOH); 11.37 br. s, 1 H (NH); 8.12 m (2 arom. H); 7.83 m (2 arom. H); 2.59 s, 3 H (CH_3).

Synthesis of Imidazol-2-ones (**7**)

To the suspension of **1a** (0.17 g, 1.0 mmol) or **2a** (0.23 g, 1.0 mmol) in CH_2Cl_2 (5 ml), cooled with an external ice-water bath, a solution of freshly distilled Ac_2O (1.8 g, 17.6 mmol) in CH_2Cl_2 (6 ml) was added dropwise. Then, the reaction solution was allowed to warm to room temperature and subsequently stirred for 12 h. The excess of MeOH was added carefully while stirring for another 15 min, and the solvents were removed in vacuum (1–5 Torr). Crude product **7** was recrystallized to give a colorless solid.

N-Methyl-1,5-dimethyl-2-oxo-2,3-dihydro-1H-imidazole-4-carboxamide (**7a**). Yield 82 mg (48%). Colorless crystals, m.p. 272–273 °C (decomp.) (EtOH). IR (KBr): 3370 s, 1693 vs, 1645 s, 1598 s, 1557 s, 1431 m, 1372 m. ^{1}H NMR (200 MHz, DMSO-d_6): 9.96 br. s, 1 H (NH); 7.34 br. d, 1 H (NH); 3.06 s, 3 H (NMe, imidazole); 2.69 d, 3 H, J = 4.6 Hz (NH**Me**); 2.32 s, 3 H (Me). ^{13}C NMR (50 MHz, DMSO-d_6): 160.3, 152.2 2s (2 C=O); 127.1, 111.0 2s (2 arom. C); 26.6, 25.6, 9.6 3q (3 Me). EI-HRMS: 169.0847 (M^+, $C_7H_{11}N_3O_2^+$; calculated 169.0851).

N-Phenyl-1,5-dimethyl-2-oxo-2,3-dihydro-1H-imidazole-4-carboxamide (**7b**). Yield 168 mg (73%). Colorless solid, m.p. 299–304 °C (decomp.) (MeOH). IR (KBr): 1695 vs, 1663 vs, 1629 vs, 1601 m, 1550 s, 1499 m, 1486 m, 1435 m, 1353 s, 1239 m, 749 m. ^{1}H NMR (200 MHz, DMSO-d_6): 10.34, 9.22 br. 2s, 2 H (2 NH); 7.64–7.61 m (2 arom. H); 7.36–7.28 m (2 arom. H); 7.09–7.02 m (1 arom. H); 3.11 s, 3 H (NMe); 2.38 s, 3 H (Me). ^{13}C NMR (50 MHz, DMSO-d_6): 158.0, 152.1 2s (2 C=O); 139.0, 129.5, 110.7 3s (3 arom. C); 128.9,

123.5, 119.8 3d (5 arom. CH); 26.7, 9.8 2q (2 Me). EI-HRMS: 231.1013 (M^+, $C_{12}H_{13}N_3O_2^+$; calculated 231.1008).

Synthesis of Imidazole-2-thiones (**8**)

To the magnetically stirred solution of **1a** (0.26 g, 1.5 mmol) or **2a** (0.35 g, 1.5 mmol) in CH_2Cl_2 (10 ml), a solution of 2,2,4,4-tetramethylcyclobutane-1,3-dithione (**9**; 0.19 g, 1.1 mmol) in dichloromethane (2 ml) was added at 0 °C. When the addition was complete, the ice bath was removed and the stirring was continued overnight. Next day, the solvent was evaporated to dryness, the crude product was washed with ether twice and purified by recrystallization from EtOH.

N-Methyl-1,5-dimethyl-2-thioxo-2,3-dihydro-1H-imidazole-4-carboxamide (**8a**). Yield 0.26 g (91%). Colorless crystals, m.p. 263–264 °C (decomp.). IR (KBr): 3300–3050 vs (br.), 1640 vs, 1606 s, 1556 s, 1489 s, 1447 m, 1422 m, 1405 m, 1383 m, 1371 s, 1273 m. ^{1}H NMR (200 MHz, DMSO-d_6): 12.21 br. s, 1 H (NH); 7.71 br. d, 1 H (NH); 3.43 s, 3 H (NMe, imidazole); 2.72 d, 3 H, J = 4.6 Hz (NH**Me**); 2.42 s, 3 H (Me). ^{13}C NMR (50 MHz, DMSO-d_6): 161.4, 159.0 2s (C=S, C=O); 132.3, 117.7 2s (2 arom. C); 30.7, 25.7, 10.1 3q (3 Me). EI-HRMS: 185.0627 (M^+, $C_7H_{11}N_3OS^+$; calculated 185.0623).

N-Phenyl-1,5-dimethyl-2-thioxo-2,3-dihydro-1H-imidazole-4-carboxamide (**8b**). Yield 0.30 g (80%). Colorless crystals, m.p. 284–288 °C (decomp.). IR (KBr): 3250–2900 vs (br.), 1667 vs, 1600 s, 1544 s, 1498 s, 1444 s, 1366 s, 1242 m, 760 m. ^{1}H NMR (200 MHz, DMSO-d_6): 12.48 br. s, 1 H (NH); 9.58 br. s, 1 H (NH); 7.66–7.64 m (2 arom. H); 7.35–7.33 m (2 arom. H); 7.10–7.08 m (1 arom. H); 3.47 s, 3 H (NMe); 2.49 s, 3 H (Me). ^{13}C NMR (50 MHz, DMSO-d_6): 161.7, 156.6 2s (C=S, C=O); 138.7, 134.2, 117.4 3s (3 arom. C); 128.9, 123.9, 119.8 3d (5 arom. CH); 30.8, 10.3 2q (2 Me). EI-HRMS: 247.0780 (M^+, $C_{12}H_{13}N_3OS^+$; calculated 247.0779).

Synthesis of *N*-Methyl-2-(4-fluorophenyl)-1,5-dimethyl-3-oxido-1*H*-imidazole-4-carboxamide (**10**)

A solution containing **1a** (0.80 g, 4.7 mmol), (*p*-bromo)fluorobenzene (0.75 g, 4.3 mmol), $Pd(OAc)_2$ (50 mg, 5 mole %), PPh_3 (170 mg, 15 mole %) and anhydrous K_2CO_3 (1.2 g, 8.6 mmol) in dry MeCN (10 ml) was heated at 75 °C under argon atmosphere for 6 h. The reaction solution was diluted with the $CHCl_3$–MeOH (8:2) mixture (50 ml), filtered through the celite plug, and the filtrate was evaporated to dryness. The obtained solid was purified by column chromatography (SiO_2, $CHCl_3$, then $CHCl_3$–MeOH (95:5), R_F 0.43) to give **10** (0.87 g, 70%) as a colorless solid, m.p. 227–228 °C (decomp.) ($CHCl_3$–Et_2O). IR (KBr): 3100–2850 m (br.), 1659 vs, 1604 s, 1568 m, 1563 m, 1471 m, 1408 m, 1378 m, 1293 m, 1230 m, 1164 m, 852 w, 837 w, 658 w, 605 w, 580 w. ^{1}H NMR (400 MHz, $CDCl_3$): 10.91 br. s, 1 H (NH); 7.87 br. s (2 arom. H); 7.42 br. s (2 arom. H); 3.53 s, 3 H (NMe); 2.82 s, 3 H (NH**Me**); 2.57 s, 3 H (Me). ^{13}C NMR (100 MHz, DMSO-d_6): 162.6 d, $^1J_{C\text{-}F}$ = 247 (1 arom. C); 160.0 s (C=O); 132.6 d, $^3J_{C\text{-}F}$ = 9 (2 arom. CH); 130.0, 128.4, 119.8 3s (3 arom. C); 119.9 d, $^4J_{C\text{-}F}$ = 3 (1 arom. C); 115.6 d, $^3J_{C\text{-}F}$ = 22 (2 arom. CH); 31.8, 24.5, 9.4 3q (3 Me). EI-HRMS: 263.1064 (M^+, $C_{13}H_{14}FN_3O_2^+$; calculated 263.1070).

Synthesis of *N*-[1-(4-Methoxyphenyl)-1*H*-(1,2,3-triazol-4-ylmethyl)]-1,5-dimethyl-3-oxido-1*H*-imidazole-4-carboxamide (**11**)

A solution of **1e** (0.16 g, 0.8 mmol) and 1-azido-4-methoxybenzene·2 MeOH (1.06 g, 5.0 mmol) (added in two equal portions – the second one after ca. 40 h) in ethanol (30 ml) was refluxed for 80 h. The solvent was removed and the obtaned material was filtered through the silica gel plug (Me_2CO, then MeOH). The crude product obtained thereby was purified by column chromatography (SiO_2, MeOH). Yield 0.19 g (67%). Colorless crystals, m.p. 206–210 °C (decomp.) (CH_2Cl_2–acetone). IR (KBr): 3110–2840 s (br.), 1652 s, 1602 s, 1560 m, 1547 m, 1518 s, 1440 m, 1289 m, 1248 m, 1226 m, 1189 m, 1038 m, 839 m, 620 m, 602 m. ^{1}H NMR (400 MHz, DMSO-d_6): 10.79 br s, 1 H (NH); 8.66, 8.60 2s, 2 H (imidazole, triazole); 7.79, 7.12 2d, 4 H, J = 8.8 (Ph); 4.61 d, 2 H, J = 5.6 (-CH_2-); 3.82, 3.60 2s, 6 H (OMe, NMe); 2.52 s, 3 H (Me). ^{13}C NMR (100 MHz, DMSO-d_6): 157.7 s (C=O); 159.2, 145.7, 131.9, 130.6, 127.2 5s (5 arom. C); 122.2, 121.7, 120.7, 114.7 4d (6 arom. CH); 55.6 q (OMe); 34.4 t (-CH_2-); 32.5 q (NMe); 9.5 q (Me). ESI-MS: 707 (100, $[M + M + Na]^+$), 365 (37, $[M + Na]^+$), 343 (26, $[M + H]^+$). For $C_{16}H_{18}N_6O_3$ (342.14) calculated: 56.12% C, 5.30% H, 24.56% N; found: 55.89% C, 5.07% H, 24.76% N.

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