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Synthesis of *N*-acylbenzotriazole using acid anhydride

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This manuscript is dedicated to Dr. Vinod K. Tiwari for his 15 years contribution in benzotriazole chemistry.

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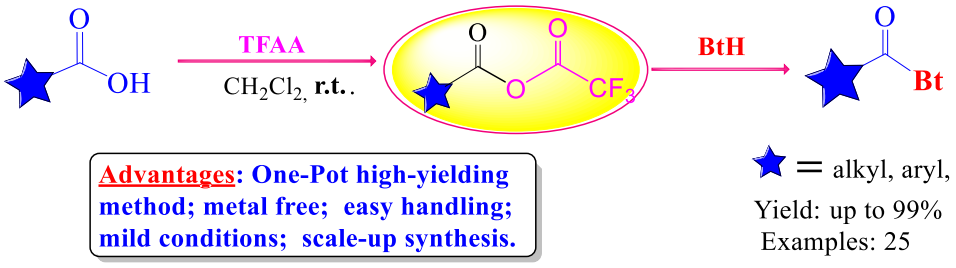
Abstract

A novel approach has been adopted for the conversion of carboxylic acids into corresponding *N*-acyl benzotriazoles utilizing acid anhydride. Our trial has ascertained 2,2,2-trifluoroacetic anhydride in anhydrous dichloromethane as the best candidate to achieve the targeted goal. The reliable and reproducible outcomes of the developed method are easy handling, wide substrate scope, and one-pot high-yielding under mild reaction condition. Moreover, the elimination of external base usage makes this procedure of utmost advantage in *N*-acyl benzotriazole synthesis.



Keywords: *N*-acylbenzotriazole, benzotriazole, acid anhydride, coupling reaction

Introduction

Decades of effort have empsasized the utility of *N*-Acyl benzotriazoles as a neutral acylating reagent. Besides, it has a diverse range of pharmacological importance, as antibacterial, antifungal, anti-helmentic, anti-protozoal, anti-cancer, anti-oxidative, anti-depressant, anti-corrosive, and anti-tubercular.[1-3] Owing to its ability to generate highly stable intermediates with the desired and, easy propagation towards the final product, benzotriazole methodology raised great attention among scientists around the globe.[4-6] In neutral and mild conditions, *N*-acylbenzotriazoles are the most dependable and reliable substitute for acid chlorides to achieve esters, peptides, amides, acid azides, diketones, oxazolines and, thiazolines *via N*-, *O*-, *S*-, and *C*-acylations.[7-22] It has also been used for the synthesis of tetrazole, urea, carbamate, and thiocarbamates via Curtius rearrangement.[23,24] Interestingly, the benzotriazole ring cleavage (BtRC) chemistry is proven to have a pivotal role in the synthesis of *N*-phenylamides and benzoxazoles.[25-28]

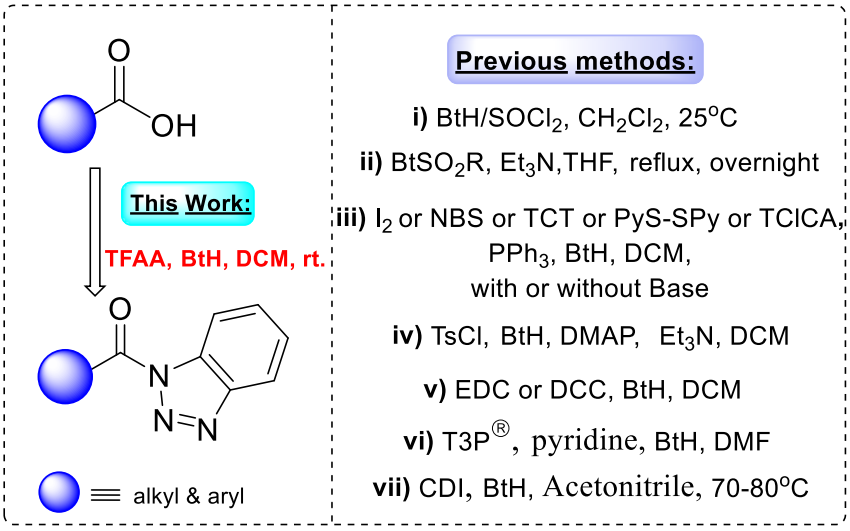


Figure 1. Common approaches for the synthesis of *N*-Acyl benzotriazoles from carboxylic acids.

In the literature, there are multiple synthetic routes for the preparation of *N*-acylbenzotriazoles from respective carboxylic acid motifs. Thus, to facilitate their prepartion, some specific sets of reagents are thionyl chloride (3-4 equiv.),[29] 1-(methane sulfonyl chloride) with Et_3N,[10] I_2/PPh_3 or NBS/PPh_3 or, TCT/PPh_3, PyS-SPy/PPh_3, TClCA/PPh_3 or, CCl_3CN or, T_3P® with or without base,[30-37] tosyl chloride with base,[38] EDC or DCC,[39] and acetonitrile/CDI[40] (Figure 1). However, these reactants have multiple disadvantages including significant toxicity in some cases, external base usage, and poor yields. To overcome these drawbacks, we intended to introduce a new reagent 'a mixed carboxylic anhydride' to achieve a high yield of *N*-acylbenzotriazoles. Mixed carboxylic anhydrides generally consist of a sterically hindered part of an acid or, a good leaving group which facilitates the amide formation in presence of 1*H*-benzotriazole.

Thus, in the present work, we report a convenient novel route to generate a library of *N*-acyl benzotriazoles by employing mixed carboxylic anhydride '2,2,2-trifluoroacetic anhydride' as a suitable alternative.

Results and Discussion

The schematic presentation (Figure 2A) includes a summary of all the previous investigations made to obtain *N*-acylbenzotriazole *via* activation of carboxylic acid. In our investigation the acid anhydride has been utilized as activating reagent for the formation of *N*-acyl benzotriazole analogues Figure 2B.

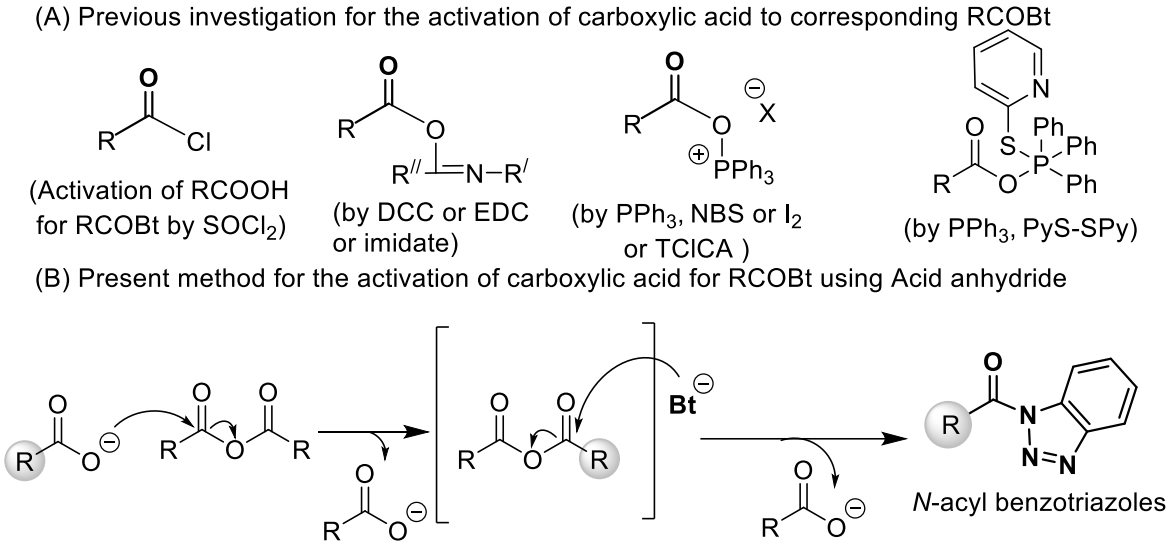
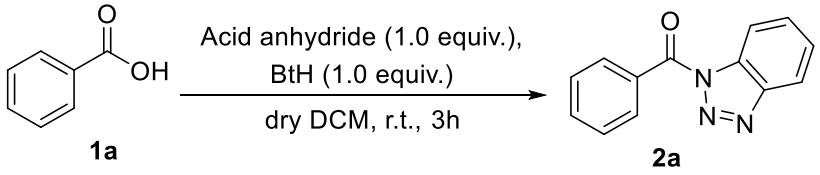


Figure 2. Schematic presentation of the previous and present activation methods for carboxylic acid to obtain *N*-acyl benzotriazoles

To examine the proposed schemes and, utility of acid anhydride as the reagent to produce *N*-acyl benzotriazoles, the first reaction was carried out with benzoic acid (1.0 equiv.) in dry DCM with a range of available acid anhydrides (1.0 equiv.). After five minutes of stirring, *1H*-benzotriazole (1.0 equiv.) was added to the reaction mixture and was allowed to stir for 3 hours. The reaction afforded the targeted *N*-benzoyl benzotriazole **2a** in 67% yield with 2,2,2-trifluoroacetic anhydride (Table 1, entry 1).

Table 1. Proto-type reaction for the synthesis of *N*-acyl benzotriazoles with various acid anhydride**.**



1a **2a**

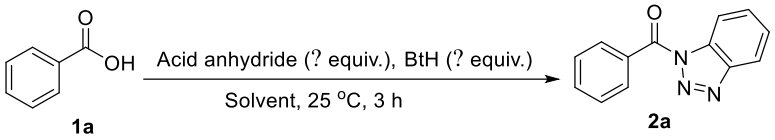
entry[a]	Acid anhydride	Yield (%)[b]
1	2,2,2-trifluoroacetic anhydride	67
2	Acetic anhydride	53
3	pivalic anhydride	49[c]
4	benzoic anhydride	99
5	Phthalic anhydride	0
6	Succinic anhydride	0

[a]Molar ratio: *benzoic acid* (1.0 mmol), [b]Reported after purification by column chromatography (SiO_2). [C]formation of 33% 1-(1*H*-benzo[d][1,2,3]triazol-1-yl)-2,2-dimethylpropan-1-one

During the optimization process, some notable facts emerged. Interestingly, a side product, 1-(1*H*-benzo[d][1,2,3]triazol-1-yl)-2,2-dimethylpropan-1-one was obtained with pivalic anhydride (entry 3, table 1). Thereafter, an outstanding yield with benzoic anhydride was observed (entry 4, table 1). It can be explained on the basis of two possibilities, i) the direct reaction of benzoic anhydride with 1*H*-benzotriazole or, ii) the formation of new favorable mixed acid anhydride followed by the addition of 1*H*-benzotriazole. However, the sequence of reagent addition has a great influence over the nature of products formed. Thus, when benzoic acid was added to a solution of 2,2,2-trifluoroacetic anhydride and 1*H*-benzotriazole, , (trifluoroacetyl)benzotriazole was obtained as the major product.[41]

Summary of the experimental trials revealed 2,2,2-trifluoroacetic anhydride as the best reagent for the proto-type reaction (table 1). To accomplish the dependable and reliable optimized condition for the proposed scheme, several permutations and combinations were tried, Table 2. Combinations using different quantities of 2,2,2-trifluoroacetic anhydride and BtH were tried (entries 1-8, Table 2), 1.0 equiv. of 2,2,2-trifluoroacetic anhydride with 2.5 equiv. of BtH (entry 6, table 2) afforded the best yield. Furthermore, the solvent optimization has been processed with the optimized amount of reagent (entry 6, table 2) and, observed that dichloromethane, chloroform and, toluene have comparable outcomes with little variation (Table 2, entries 6, 9-16). Therefore, the low boiling point of dichloromethane with high solubility property for a large variety of carboxylic acid influenced the decision to make it the preferred solvent for the optimized reaction. Lastly, the effect of temperature and time on the reaction and yield was studied. There was no variation in the yield with the temperature variation from 0 ℃ to 35 ℃ and time variation (1h to 16h) under the optimized reaction conditions.

Table 2. Reaction optimization study



1a 2a

entry[a]	2,2,2-trifluoroacetic anhydride (equiv)	BtH (equiv.)	Solvent [b]	Yield (%) [c]
1	1.0	2.0	DCM	91
2	1.0	1.0	DCM	67
3	1.0	1.0	DCM	67[d]/66[e]
4	1.0	2.1	DCM	94
5	1.0	3.0	DCM	97
6	1.0	2.5	DCM	97
7	0.5	2.5	DCM	45
8	0.0	2.5	DCM	00
9	1.0	2.5	Toluene	93
10	1.0	2.5	$CHCl_3$	95
11	1.0	2.5	DMF	67
12	1.0	2.5	THF	86
13	1.0	2.5	Dioxane	25
14	1.0	2.5	Acetone	33
15	1.0	2.5	TEA	42
16	1.0	2.5	Ethyl	54

			acetate	

[a] Molar ratio: carboxylic acid (1.0 mmol, 0.1 g), [b]dry solvents, yields [c]3 h, [d]8 h and [e]16 h reported after purification by column chromatography (SiO_2).

After optimizing the reaction conditions, we evaluated yields deviation with various carboxylic acids substrates, i.e.; aromatic and aliphatic. The final results did not show much change in the yields with the substitution variation on aromatic ring of carboxylic acids and, the length of aliphatic chain in aliphatic carboxylic acids.

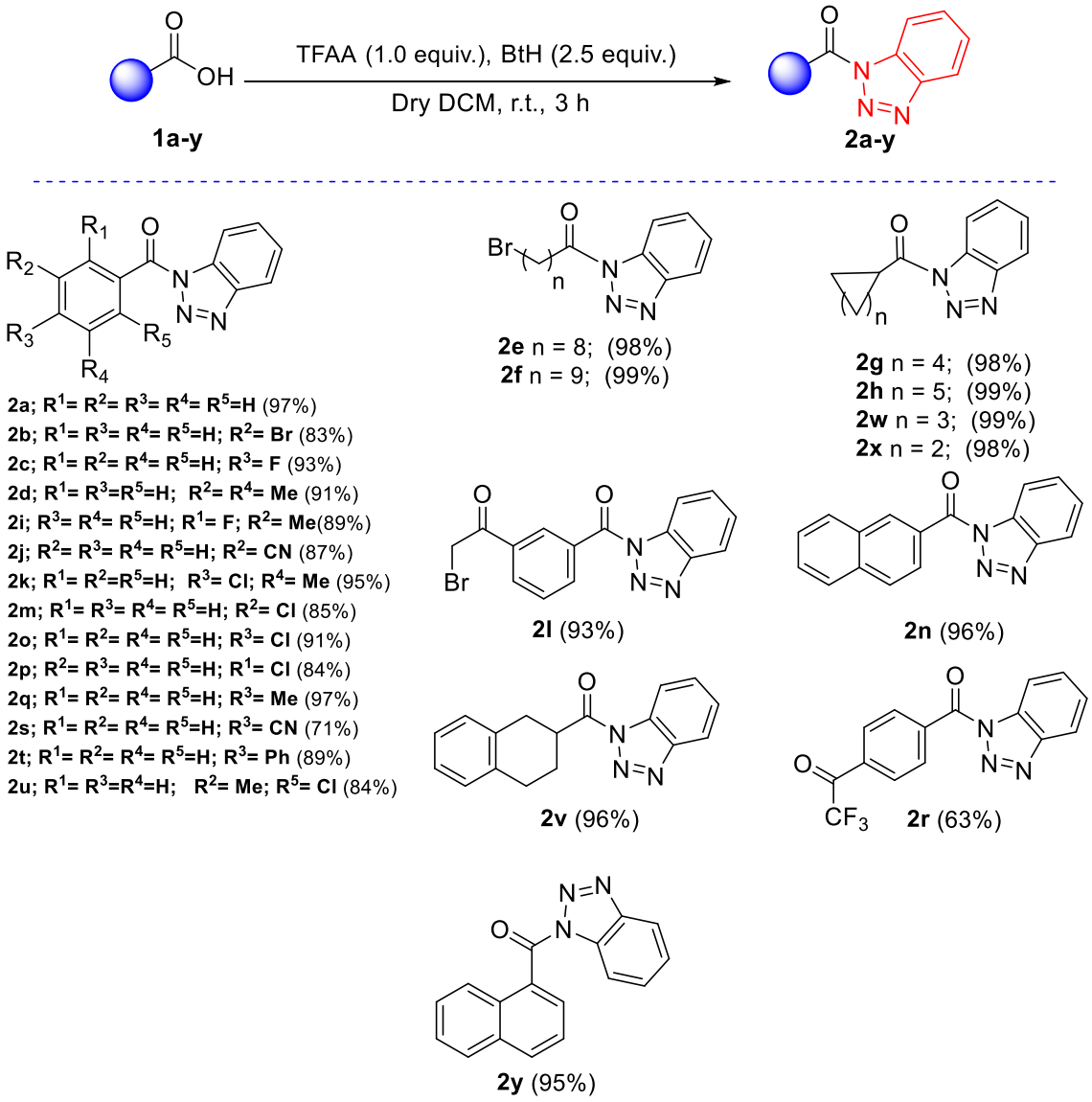
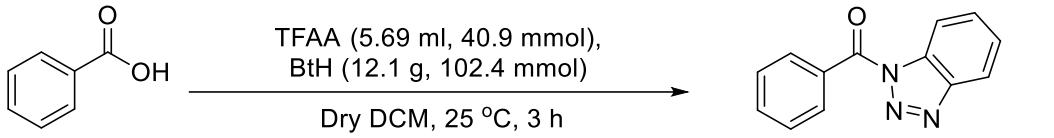


Figure 3. Molar ratios: carboxylic acids (**1a-y**) (1.0 equiv. 0.1 g), benzotriazole (2.5 equiv.), 2,2,2-trifluoroacetic anhydride (1.0 equiv.), Yields after column chromatography (SiO_2).

The crude mass was purified by the flash column chromatography with varying gradient (0-15 %) of ethyl acetate/*n*-hexane to obtain highly pure compounds **2a-y** (Figure 3).

Synthesis of *N*-acylbenzotriazole: reaction on gram scale

For quantitative generalization, we also carried out the reaction on gram scale, which contributed to enhance the synthetic utility of the present method for *N*-acylbenzotriazole development. In the trial, we found the reaction proceeds as efficiently as on milligram scale, as for 5g scale and, the final product *N*-benzoyl benzotriazole **2a** was obtained in 91% yield. Therefore, the reaction protocol is applicable for both milligram and gram scales (Scheme 1).

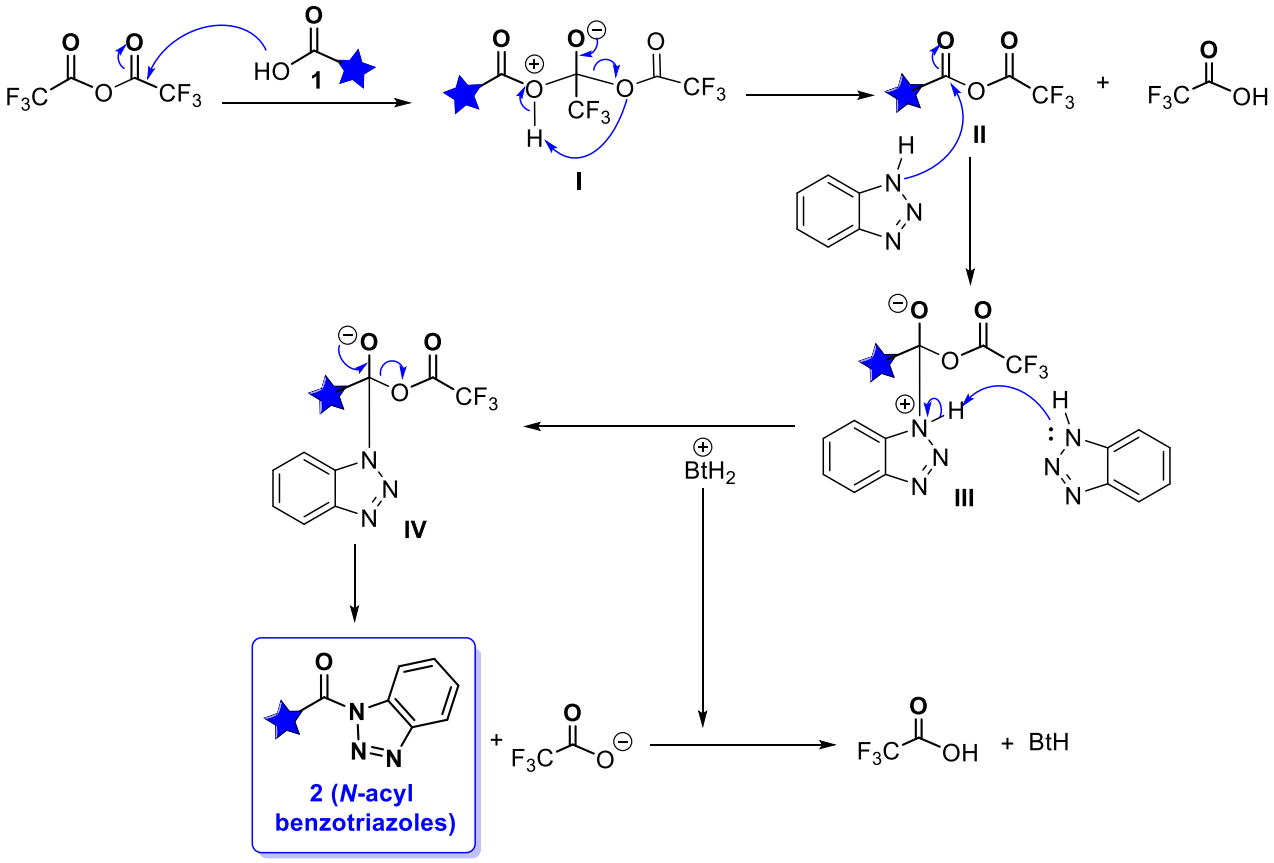


1a; (5.0g, 40.9 mmol) **2a**; (8.32g, 37.2 mmol, 91%)

Scheme 1. Gram scale Synthesis of *N*-acyl benzotriazole **2a**

Plausible mechanism of the reaction

Based on previous reports and our results the reaction may initiate with the formation of the mixed acid anhydride as intermediate **II**, from 2,2,2-trifluoroacetic anhydride and carboxylic acid.[42] Thereafter, the successive nucleophilic attack of 1*H*-benzotriazole on the intermediate **II** may lead to the formation of **III**, which on deprotonation by the help of another 1*H*-benzotriazole gives intermediate **IV,** which leaves carboxylate ion to give 2 (*N*-acyl benzotriazole) as the final product.



Scheme 2. Plausible reaction mechanism for the synthesis of *N*-acylbenzotriazole using 2,2,2-trifluoroacetic anhydride

Conclusions

In conclusion, we have screened various acid anhydrides to develop the most practicable, effective and, high yield (up to 99%) methodology to synthesize N-acylbenzotriazoles as the final product. Our study showed that 2,2,2-trifluoroacetic anhydride was the suitable reagent to achieve the target, from a range of carboxylic acids including aliphatic and aromatic substitutions. The designed and, developed methodology has showcased promising application and is found to be equally useful for the scale up synthesis. Therefore, we can hope that it will open up more opportunities for versatile synthesis practices.

Experimental Section

General. All the starting materials and reagents were purchased from commercial source Sigma Aldrich, and Alfa Aesar. These materials were used without further purification or drying. Thin-layer chromatography (TLC) was performed on, pre-coated aluminium plates, and display with Ultraviolet lamp (λ_{max} = 254 nm). Column chromatography was carried out on silica gel (230 - 400 mesh, Merck). *n*-Hexane and ethyl acetate were used for the column chromatography. ^{1}H, and ^{13}C NMR spectra were recorded at 400 and 100 MHz, respectively by Bruker Avance NEO-400. Chemical shifts given in ppm downfield from residual solvent signal at 7.26 ppm for ^{1}H NMR and 77.16 ppm for ^{13}C NMR; *J* values in Hz. Infrared spectra recorded as Nujol mulls in KBr plates.

General procedure for synthesis of N-acylbenzotriazoles. 2,2,2-Trifluoroacetic anhydride (0.114 ml, 1.0 equiv., 0.819 mmol) was added into a solution of carboxylic acid **1a** (0.1 g, 1.0 equiv., 0.819 mmol) in dry DCM (5 ml) in a round bottom flask, stirred for 5 minutes at room temperature. Then, 1*H*-benzotriazole (0.243 g, 2.5 equiv., 2.049 mmol) was added and, the resulting mixture was stirred for next 3 hours at room temperature. After completion of reaction (monitored by TLC), the reaction mass was concentrated under reduced pressure to obtained crude materials. The crude was purified by flash column chromatography (SiO_2) using (0-15%) ethyl acetate/*n*-hexane as eluent, which afforded compound **2a** with 97 % yield.

Gram scale procedure for synthesis of (1*H*-1,2,3-benzotriazole-1-yl)-phenyl-methanone. 2,2,2-Trifluoroacetic anhydride (5.69 ml, 1.0 equiv., 40.9 mmol) was added into a solution of Carboxylic acid **1a** (5.0 g, 1.0 equiv., 40.9 mmol) and dry DCM (250 ml), stirred for 15 minutes. Then, 1*H*-Benzotriazole (12.1 g, 2.5 equiv., 102.4 mmol) was added and, the resulting reaction mixture was stirred for 3 hours at room temperature. After completion of reaction (monitored by TLC), the reaction mass was concentrated under reduced pressure and the resulting crude was subjected to flash column chromatography (SiO_2) using 0-15% ethyl acetate/*n*-hexane as eluent to afford product **2a** (91 %) in pure form.

Physical data of developed N-acylbenzotriazoles

(1*H*-1,2,3-Benzotriazole-1-yl)-phenyl-methanone (2a).[34] White crystalline Solid, yield 0.177g (97%); R_f = 0.6 (10% ethyl acetate/n-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.41 (d, *J* 8.0 Hz, 1H), 8.23-8.21 (m, 2H), 8.18 (d, *J* 8.4 Hz, 1H), 7.74-7.68 (m, 2H), 7.61-7.54 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 166.8, 145.8, 133.7, 132.4, 131.8, 131.5, 130.4, 128.5, 126.4, 120.2 and 114.8 ppm.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(3-Bromophenyl)methanone (2b).[28] White colour solid, yield 0.124g (83%); R_f = 0.6 (5% ethyl acetate/n-hexane);^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.40-8.36 (m, 2H), 8.20-8.16 (m, 2H), 7.83-

7.81 (d, *J* 8.4 Hz, 1H), 7.75-7.71 (m, 1H), 7.60-7.56 (m, 1H) 7.49-7.45 (t, *J* 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 165.4, 145.9, 136.7, 134.5, 133.4, 132.3, 130.8, 130.4, 130.0, 126.7, 122.6, 120.4 and 114.9 ppm.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(4-fluorophenyl)methanone (2c).[43] White crystalline Solid, yield 0.160g (93%);R_f = 0.5 (5% ethyl acetate/*n*-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.40 (d, *J* 8.4 Hz, 1H), 8.34-8.30 (m, 2H), 8.18 (d, *J* 8.4 Hz, 1H), 7.72 (t, *J* 7.2 Hz, 1H), 7.59- 7.55 (m, 1H), 7.29- 7.27 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 166.2 (d, *J* 255.2 Hz), 165.5, 145.8, 134.7 (d, *J* 9.5 Hz), 132.5, 130.6, 127.7, 126.5, 120.4, 115.9 (d, *J* 21.9 Hz) and 114.9 ppm.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(3,5-dimethylphenyl)methanone (2d).[35] White crystalline Solid, yield 0.152g (91%); R_f = 0.5 (5% ethyl acetate/*n*-hexane);^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.39 (d, *J* 8.0 Hz, 1H), 8.18 (d, *J* 8.0 Hz, 1H), 7.79 (s, 2H), 7.72-7.69 (t, *J* 8.0 Hz, 1H), 7.57-7.53 (t, *J* 7.2 Hz, 1H), 7.32 (s, 1H), 2.44 (s, 6H) ; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 167.2, 145.6, 138.1, 135.4, 132.2, 131.9, 131.1, 129.3, 127.0, 120.4, 114.8 and 21.2 ppm.

1-(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)-9-bromononan-1-one (2e). oil at 25 °C, yield 0.137g (98%); R_f = 0.8 (10% ethyl acetate/*n*-hexane); IR (KBr):ν_{max} 2929, 2861, 1702, 1450, 1409, 1374, 971, 745 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.30 (d, *J* 8.4 Hz, 1H), 8.12 (d, *J* 8.0 Hz, 1H), 7.67-7.63 (m, 1H), 7.52-7.49 (m, 1H), 3.44-3.39 (m, 4H), 1.93-1.84 (m, 4H), 1.49-1.37 (m, 8H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 172.7, 146.2, 131.2, 130.4, 126.1, 120.2, 114.5, 35.5, 34.0, 32.8, 29.1, 29.0, 28.6, 28.1 and 24.4 ppm. ESI-MS: Calc. for $C_{15}H_{21}BrN_3O$ $(M+H)^+$: 338.08; found: 338.10.

1-(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)-10-bromodecan-1-one (2f). oil at 25 °C, yield 0.136g (99%); R_f = 0.8 (10% ethyl acetate/*n*-hexane); IR (KBr):ν_{max} 2928, 2915, 2851, 1686, 1467, 1426, 1407, 1292, 1231, 1205, 1185, 926, 744 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.30 (d, *J* 8.0 Hz, 1H), 8.12 (d, *J* 8.4 Hz, 1H), 7.67-7.63 (m, 1H), 7.52-7.49 (m, 1H), 3.44-3.38 (m, 4H), 1.92-1.83 (m, 4H), 1.50-1.33 (m, 10H);^{13}C NMR (100 MHz, $CDCl_3$): δ = 172.7, 146.2, 131.1, 130.4, 126.1, 120.1, 114.5, 35.5, 34.0, 32.8, 29.3, 29.2, 29.1, 28.7, 28.2 and 24.4 ppm. ESI-MS: Calc. for $C_{16}H_{23}BrN_3O$ $(M+H)^+$: 352.10; found: 352.15.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(cyclohexyl)methanone (2g).[44] White crystalline solid, yield 0.175g (98%); R_f = 0.5 (10% ethyl acetate/*n*-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.30 (d, *J* 8.4 Hz, 1H), 8.12 (d, *J* 8.4 Hz, 1H), 7.65 (t, *J* 7.6 Hz, 1H), 7.50 (t, *J* 7.6 Hz, 1H), 3.95-3.87 (tt, *J* 3.2&4.8 Hz, 1H), 2.17-2.12 (m, 2H), 1.91-1.81 (m, 2H), 1.77-1.65 (m, 3H), 1.55-1.44 (m, 2H), 1.39-1.25 (m, 1H);^{13}C NMR (100 MHz, $CDCl_3$): δ = 175.7, 146.2, 131.3, 130.3, 126.1, 120.1, 114.7, 43.3, 29.2, 25.8 and 25.4 ppm.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(cycloheptyl)methanone (2h). White crystalline solid, yield 0.169g (99%); mp 55-56 °C; R_f = 0.5 (10% ethyl acetate/*n*-hexane); IR (KBr):ν_{max} 2921, 2854, 1729, 1596, 1485, 1461, 1448, 1384, 1347, 1320, 1285, 1064, 977 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.30 (d, *J* 8.0 Hz, 1H), 8.12 (d, *J* 8.4 Hz, 1H), 7.66-7.62 (m, 1H), 7.52-7.48 (m, 1H), 4.13-4.06 (m, 1H), 2.20-2.13(m, 2H), 1.95-1.84 (m, 4H), 1.72-1.61 (m, 6H);^{13}C NMR (100 MHz, $CDCl_3$): δ = 176.6, 146.3, 131.4, 130.3, 126.1, 120.1, 114.7, 44.5, 31.0, 28.4 and 26.6 ppm. ESI-MS: Calc. for $C_{14}H_{18}N_3O$ $(M+H)^+$: 244.14; found: 244.15.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(2-fluoro-3-methylphenyl)methanone (2i). White crystalline Solid, yield 0.147g (89%); mp 113-114 °C; R_f = 0.5 (10% ethyl acetate/n-hexane); IR (KBr):ν_{max} 1716, 1618, 1606, 1588, 1487, 1469, 1451, 1373, 1290, 1206, 1206, 1152, 1049, 956, 840, 797, 771, 749 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.40 (d, *J* 8.4 Hz, 1H), 8.17 (d, *J* 8.4 Hz, 1H), 7.73 (t, *J* 7.6 Hz, 1H), 7.60-7.54 (m, 2H), 7.50-7.47 (t, *J* 7.2 Hz, 1H), 7.25-7.21 (m, 1H), 2.38 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.7, 158.9 (d, *J* 252.1 Hz), 146.2, 136.0 (d, *J* 5.7 Hz), 131.6, 130.6, 128.7, 126.6, 126.3 (d, *J* 17.1 Hz), 123.9 (d, *J* 4.0 Hz), 121.2 (d, *J* 14.5 Hz), 120.4, 114.5 and 14.7 (d, *J* 4.1 Hz) ppm. ESI-MS: Calc. for C14H11FN3O $(M+H)^+$: 256.08; found: 256.15.

3-(1*H*-Benzo[*d*][1,2,3]triazole-1-carbonyl)benzonitrile (2j).[35] White solid, yield 0.146g (87%); R_f = 0.5 (10% ethyl acetate/n-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.55 (s, 1H), 8.48 (d, *J* 8.0 Hz, 1H), 8.41 (d, *J* 8.4 Hz, 1H),

8.21 (d, *J* 8.4 Hz, 1H), 7.97 (d, *J* 7.6 Hz, 1H) 7.78-7.71 (m, 2H), 7.60 (d, *J* 7.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.7, 145.9, 136.5, 135.7, 135.3, 132.8, 132.1, 131.0, 129.5, 126.9, 120.5, 117.7, 114.8 and 113.2.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(4-chloro-3-methylphenyl)methanone (2k). White crystalline Solid, yield 0.151g (95%); mp 128-130 °C; R_f = 0.5 (5% ethyl acetate/*n*-hexane); IR (KBr):ν_{max} 1699, 1596, 1449, 1391, 1365, 1319, 1284, 1229, 1041, 941, 880, 807, 745 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.38 (d, *J* 8.4 Hz, 1H), 8.18 (d, *J* 8.4 Hz, 1H), 8.11 (s, 1H), 8.03-8.01 (dd, *J* 1.6, 6.8 Hz, 1H), 7.73-7.70 (t, *J* 7.6 Hz, 1H), 7.58-7.54 (t, *J* 8.0 Hz, 2H), 2.50 (s,3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 166.0, 145.8, 140.7, 136.8, 134.1, 132.4, 130.64, 13.60, 129.9, 129.4, 126.5, 120.3, 114.9 and 20.3 ppm. ESI-MS: Calc. for $C_{14}H_{11}ClN_3O$ $(M+H)^+$: 272.05; found: 272.15.

1-(3-(1*H*-Benzo[*d*][1,2,3]triazole-1-carbonyl)phenyl)-2-bromoethan-1-one (2l). White crystalline Solid, yield 0.131g (93%); mp 119-120 °C; R_f = 0.5 (5% ethyl acetate/*n*-hexane); IR (KBr):ν_{max} 1698, 1449, 1360, 1250, 1103, 1028, 938, 730 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.81 (s, 1H), 8.48 (d, *J* 8.0 Hz, 1H), 8.43(d, *J* 8.4 Hz, 1H), 8.33 (d, *J* 7.6 Hz, 1H), 8.21 (d, *J* 8.4 Hz, 1H),7.77-7.73 (td, *J* 2.4, 5.6 Hz, 2H), 7.61-7.58 (t, *J* 7.2 Hz, 1H), 4.51 (s, 2H) ; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 190.3, 165.7, 145.9, 136.6, 134.3, 133.6, 132.4, 132.3, 132.2, 130.9, 129.3, 126.8, 120.5, 114.9 and 30.5 ppm. ESI-MS: Calc. for $C_{15}H_{11}BrN_3O_2$ $(M+H)^+$: 344.05; found: 344.0.

(1H-Benzo[*d]*[1,2,3]triazol-1-yl)(3-chlorophenyl)methanone (2m).[33] White crystalline Solid, yield 0.140g (85%); R_f = 0.5 (5% ethyl acetate/*n*-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.39 (d, *J* 8.4 Hz, 1H), 8.21-8.18 (m, 2H), 8.13 (d, *J* 8.0 Hz, 1H), 7.73 (t, *J* 7.6 Hz, 1H), 7.67 (d, *J* 8.4 Hz, 1H), 7.59-7.51 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 165.5, 145.9, 134.7, 133.7, 133.2, 132.3, 131.7, 130.7, 129.9, 129.8, 126.7, 120.4 and 114.9 ppm.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(naphthalen-2-yl)methanone (2n).[32] White crystalline solid, yield 0.152g (96%); R_f = 0.7 (10% ethyl acetate/*n*-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.87 (s, 1H), 8.45 (d, *J* 8.4 Hz, 1H), 8.24-8.19 (m, 2H), 8.03 (t, *J* 8.8 Hz, 2H), 7.95 (d, *J* 8.4 Hz, 1H), 7.74 (t, *J* 7.6 Hz, 1H), 7.67 (t, *J* 7.2 Hz, 1H), 7.63-7.56 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 166.8, 145.9, 135.8, 134.4, 132.6, 132.3, 130.5, 130.0, 129.2, 128.6, 128.4, 127.9, 127.2, 126.7, 126.5, 120.3 and 115.0 ppm.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(4-chlorophenyl)methanone (2o).[33] Colourless solid, yield 0.149g (91%); R_f = 0.6 (10% ethyl acetate/*n*-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.39 (d, *J* 8.4 Hz, 1H), 8.22-8.17 (m, 3H), 7.73 (t, *J* 7.6 Hz, 1H), 7.59-7.55 (m, 3H);^{13}C NMR (100 MHz, $CDCl_3$): δ = 165.7, 145.9, 140.5, 133.3, 132.4, 130.7, 129.9, 129.0, 126.6, 120.4 and 114.9 ppm.

(1H-benzo[*d*][1,2,3]triazol-1-yl)(2-chlorophenyl)methanone (2p).[33] White crystalline solid, yield 0.138g (84%); R_f = 0.5 (10% ethyl acetate/*n*-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.42 (d, *J* 8.0 Hz, 1H), 8.17 (d, *J* 8.0 Hz, 1H), 7.74 (t, *J* 7.6 Hz, 1H), 7.66 (d, *J* 7.6 Hz, 1H), 7.59-7.55 (m, 3H), 7.49-7.43 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 165.9, 146.3, 133.0, 132.7, 132.5, 131.4, 130.8, 130.3, 130.2, 126.8, 126.7, 120.5 and 114.5 ppm.

(1H-Benzo[*d*][1,2,3]triazol-1-yl)(p-tolyl)methanone (2q).[31] White crystalline solid, yield 0.169g (97%); R_f = 0.5 (10% ethyl acetate/*n*-hexane);^{1}H NMR (500 MHz, $CDCl_3$): δ = 8.38 (d, *J* 8.0 Hz, 1H), 8.17-8.13 (m, 3H), 7.69 (t, *J*= 7.6 Hz, 1H), 7.54 (t, *J* 7.6 Hz, 1H), 7.38 (d, *J* 8.0 Hz, 2H), 2.48 (s,3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 166.6, 145.8, 144.9, 132.5, 132.0, 130.3, 129.2, 128.7, 126.3, 120.2, 114.9 and 21.8 ppm.

1-(4-(1*H*-Benzo[*d*][1,2,3]triazole-1-carbonyl)phenyl)-2,2,2-trifluoroethan-1-one (2r). White crystalline Solid, yield 0.092g (63%); mp 118-120 °C; R_f = 0.6 (10% ethyl acetate/n-hexane); IR (KBr):ν_{max} 1722, 1691, 1609, 1597, 1568, 1429, 1409, 1289, 1208, 1175, 1147, 1064, 1017, 930, 744, 730 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.42 (d, *J* 8.0 Hz, 1H), 8.36 (d, *J* 8.8 Hz, 2H), 8.28-8.25 (m, 2H), 8.21-8.16 (m, 1H), 7.78-7.74 (m, 1H), 7.62-7.58 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 180.1 (q, *J* 35.8 Hz), 165.6, 145.9, 137.4, 133.2, 132.1, 131.0, 130.7, 129.9 (q, *J* 2.0 Hz), 127.0, 120.6, 116.5 (q, *J* 289.4 Hz) and 114.8 ppm. ESI-MS: Calc. for $C_{15}H_{11}F_3N_4O_2$ $(M+NH3)^+$: 336.08; found: 336.10.

4-(1*H*-Benzo[*d*][1,2,3]triazole-1-carbonyl)benzonitrile (2s).[45] White colour solid, yield 0.119g (71%); R_f = 0.6 (5% ethyl acetate/n-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.41 (d, *J* 8.4 Hz, 1H), 8.33 (d, *J* 8.4 Hz, 2H), 8.20 (d,

J 8.4 Hz, 1H), 7.89 (d, *J* 8.4 Hz, 2H), 7.76 (t, *J* 7.6 Hz, 1H) 7.60 (t, *J* 7.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 165.3, 145.9, 135.4, 132.3, 132.2, 132.1, 131.0, 127.0, 120.6, 117.8, 117.0 and 114.8 ppm.

[1,1'-biphenyl]-4-yl(1*H*-benzo[*d*][1,2,3]triazol-1-yl)methanone (2t).[45] White crystalline Solid, yield 0.134g (89%); R_f = 0.5 (5% ethyl acetate/*n*-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.42 (d, *J*=8.4 Hz, 1H), 8.33 (d, *J* 8.4 Hz, 2H), 8.20 (d, *J* 8.4 Hz, 1H), 7.81 (d, *J* 8.4 Hz, 2H), 7.75-7.68 (m, 3H), 7.59-7.55 (m, 1H), 7.52-7.49 (m, 2H), 7.46-7.42 (m, 1H) ;^{13}C NMR (100 MHz, $CDCl_3$): δ = 166.5, 146.6, 145.9, 139.7, 132.5, 130.5, 130.2, 130.1, 129.1, 128.6, 127.5, 127.2, 126.4, 120.3 and 114.9 ppm.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(5-chloro-2-methylphenyl)methanone (2u). White crystalline Solid, yield 0.133g (84%); mp 130-131 °C; R_f = 0.5 (5% ethyl acetate/*n*-hexane); IR (KBr):ν_{max} 1697, 1594, 1449, 1390, 1367, 1321, 1290, 1221, 1041, 953, 883, 807, 748 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.40 (d, *J* 8.4 Hz, 1H), 8.18 (d, *J* 8.4 Hz, 1H), 7.76-7.72 (m, 1H), 7.60-7.56 (m, 2H), 7.51-7.46 (m, 1H), 7.32-7.28 (m, 1H), 2.38 (s,3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 167.1, 146.3, 136.2, 133.8, 132.4, 131.8, 131.6, 131.5, 130.8, 129.6, 126.7, 120.5, 114.6 and 19.6 ppm. ESI-MS: Calc. for $C_{14}H_{11}ClN_3O$ $(M+H)^+$: 272.05; found: 272.10.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(1,2,3,4-tetrahydronaphthalen-2-yl)methanone (2v). white wax at 25°C, yield 0.151g (96%); R_f = 0.5 (5% ethyl acetate/*n*-hexane); IR (KBr):ν_{max} 2927, 2913, 2854, 1731, 1596, 1484, 1432, 1373, 1164, 1055, 971, 928, 744 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.31 (d, *J* 8.4 Hz, 1H), 8.17 (d, *J* 8.4 Hz, 1H), 7.68-7.64 (m, 1H), 7.55-7.51 (m, 1H), 7.24-7.19 (m, 2H), 7.16-7.11 (m, 1H), 7.08 (d, *J* 7.6 Hz, 1H), 5.55-5.38 (m, 1H), 3.00-2.94 (m, 1H), 2.91-2.85 (m, 1H), 2.40-2.28 (m, 2H), 2.10-2.06 (m, 1H), 1.91-1.89 (m, 1H) ; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 174.6, 146.4, 138.0, 132.6, 131.5, 130.5, 129.7, 129.4, 127.4, 126.3, 126.2, 120.2, 114.8, 44.5, 29.2, 27.7 and 20.5 ppm. ESI-MS: Calc. for $C_{17}H_{16}N_3O$ $(M+H)^+$: 278.12; found: 278.15.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(cyclopentyl)methanone (2w).[46] White crystalline Solid, yield 0.187g (99%); R_f = 0.5 (5% ethyl acetate/*n*-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.31 (d, *J* 8.0 Hz, 1H), 8.12 (d, *J* 8.0 Hz, 1H), 7.70-7.62 (m, 1H), 7.51-7.44 (m, 2H), 4.29-4.23 (m, 1H), 2.24-2.15 (m, 2H), 2.15-2.01 (m,2H), 1.90-1.72 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 175.7, 146.1, 131.3, 130.1, 125.9, 120.0, 114.5, 44.1, 30.4 and 26.2 ppm.

(1*H*-benzo[*d*][1,2,3]triazol-1-yl)(cyclobutyl)methanone (2x).[43] White crystalline Solid, yield 0.196g (98%); R_f = 0.5 (5% ethyl acetate/*n*-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.31 (d, *J* 8.4 Hz, 1H), 8.11 (d, *J* 8.4 Hz, 1H), 7.67-7.63 (m, 1H), 7.51-7.47 (m, 1H), 4.56-4.52 (m, 1H), 2.60-2.45 (m, 4H), 2.23-2.16 (m, 1H), 2.07-2.02 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.9, 146.0, 131.1, 130.1, 125.9, 120.0, 114.3, 39.0, 25.2 and 18.4 ppm.

(1*H*-Benzo[*d*][1,2,3]triazol-1-yl)(naphthalen-1-yl)methanone (2y).[35] White crystalline Solid, yield 0.150g (95%); R_f = 0.5 (5% ethyl acetate/*n*-hexane); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.51 (d, *J* 8.4 Hz, 1H), 8.20-8.14 (m, 3H), 7.99-7.94 (m, 2H), 7.79-7.75 (m, 1H), 7.64-7.55 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 167.7, 146.3, 133.7, 133.1, 132.2, 131.1, 130.6, 130.3, 129.4, 128.8, 128.0, 126.8, 126.6, 124.9, 124.4, 120.5 and 114.8 ppm.

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Supplementary Material

Characterization data (for all the developed acyl benzotriazoles) including copies of ^{1}H and ^{13}C NMR spectra associated with this paper can be found in the online version.

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