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Features and applications of reactions of α,β-unsaturated *N*-acylbenzotriazoles with amino compounds

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1,5-Benzothiazepine-2-ones

ABSTRACT

Promoted by triethylamine, α,β-unsaturated *N*-acylbenzotriazoles reacted with amino compounds in a variety of ways. Thus, *N*-cinnamoylbenzotriazoles reacting with aromatic amines afforded novel addition products β-benzotriazolyl amides **3**, which might be normally formed from the alternative but unknown 1,4-addition of benzotriazole to *N*-cinnamoylamides. The type **3** compounds could also result from the reaction between *N*-crotonoylbenzotriazole and aliphatic amines. However, normal 1,4-addition could occur between α,β-unsaturated aliphatic *N*-acylbenzotriazoles and aromatic amines, leading to β-amino *N*-acylbenzotriazoles **4** in good yields. In addition, exclusive 1,2-addition of aliphatic amines to *N*-cinnamoylbenzotriazoles gave excellent yields of cinnamides **5**. Accordingly, three possible routes were proposed to rationalize the formation of compounds **3**–**5**. Finally, with *o*-phenylenediamine and *o*-aminothiophenol as the substrates, the 1,4- and 1,2-addition to α,β-unsaturated *N*-acylbenzotriazoles could take place concurrently and the corresponding heterocycles 1,5-benzodiazepine-2-one and 1,5-benzothiazepine-4-one were constructed, respectively.

1. Introduction

Nucleophilic additions to conjugated unsaturated systems have been the subject of numerous studies.[1] The mode of the reaction, namely, the 1,4- or 1,2-addition, has been of major interest[1e] and can be influenced by the nature of nucleophiles and conjugated unsaturated systems, temperature, additives, etc. Amines are a class of heteroatom nucleophiles that have been widely used to effect 1,4-addition, i.e., aza-Michael addition to α,β-unsaturated carbonyl compounds (activated double bonds or electron-deficient double bonds) and this organic transformation provides a facile synthesis of important natural and unnatural target molecules.[2] Among a variety of conjugated unsaturated systems investigated, α,β-ethylenic compounds such as methyl vinyl ketone, acrylonitrile, acrylate, acrylamide, vinyl sulfones, etc. were found to be particularly successful aza-Michael addition acceptors.[3] Even so, in most cases, only aliphatic amines were effective nucleophiles while aromatic amines often failed to undergo the 1,4-addition with the above Michael acceptors.[3a–k] Also, even under specific conditions where the aromatic amines underwent the aza-Michael addition smoothly,[3l–s] the unsaturated conjugated systems[3] were generally limited to methyl vinyl ketone, acrylonitrile, acrylate, and acrylamide. β-Substituted, especially, β-aryl substituted α,β-ethylenic compounds were usually not employed due to their low reactivity as Michael acceptors, although stereoselective aza-Michael addition of β-substituted α,β-ethylenic compounds has been investigated[4] but remains to be a great challenge.[5]

1,2-Addition of amines to unsaturated conjugated systems is also known. For example, both aliphatic and aromatic amines could undergo the exclusive 1,2-addition with α,β-unsaturated acyl chlorides leading to the corresponding α,β-unsaturated amides in high yields.[6]

Herein, we wish to report versatile addition reactions between amines and a special type of α,β-unsaturated amide, namely, α,β-unsaturated *N*-acylbenzotriazoles, which contain a C=C–CON functionality.

Among the most common unsaturated conjugated systems, α,β-unsaturated amides have not been studied extensively as aza-Michael acceptors due to their low reactivity except for the simple acrylamide, $CH_2{=}CHCONH_2$.[3] Two alternative strategies could be applied to effect a successful aza-Michael addition of α,β-unsaturated amides. One is to enhance the reactivity of the nucleophiles by converting amines into lithium amides so that the amines could react with α,β-unsaturated amides giving rise to the 1,4-addition products in good yields.[7] The other strategy generally

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involves the activation of α,β-unsaturated amides by introducing appropriate protecting-activating groups onto the nitrogen and thus transformation of the α,β-unsaturated amides into the corresponding imides.[8]

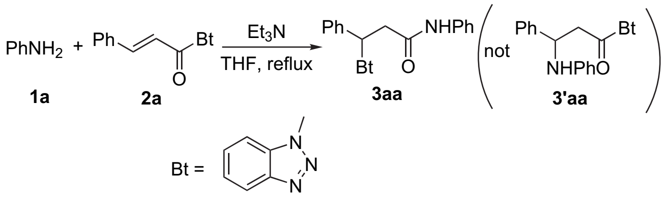
N-Acylbenzotriazoles are excellent acylating agents due to the good leaving ability of benzotriazolyl group and have found wide applications in the acylation of various nucleophiles.[9] However, in this context, α,β-unsaturated *N*-acylbenzotriazoles received much less attention and systematic studies have not been conducted on the nucleophilic attack of this type of *N*-acylbenzotriazoles. Understandingly, like ordinary *N*-acylbenzotriazoles, α,β-unsaturated *N*-acylbenzotriazoles could also be used as mild acylating agent, acting as 1,2-addition acceptor. For instance, *N*-cinnamoyl benzotriazoles have been used to prepare cinnamoyl hydrazides by acylation of hydrazine;[10] lithium enolates of ketones have also been acylated with α,β-unsaturated acylbenzotriazoles to prepare γ,δ-unsaturated β-diketones.[11] Recently, we reported the acylation of thiolates[12] and aliphatic amines[13] with *N*-cinnamoylbenzotriazoles, thus a facile synthesis of α,β-unsaturated thioesters and cinnamides has been established. Katritzky et al. reported lately that Grignard reagents could also undergo readily 1,2-addition to different α,β-unsaturated *N*-acylbenzotriazoles resulting in the formation of α,β-unsaturated ketones.[14] The above acylation reactions were considered of great interest[11] because the acylating agents used, α,β-unsaturated acylbenzotriazoles, are stable crystalline compounds, readily available, and easy to handle, thereby avoiding the usage of the corresponding acyl chlorides, which are usually unstable and difficult to handle.

In addition, α,β-unsaturated *N*-acylbenzotriazoles have been demonstrated to be very useful Michael addition acceptors as well. Our recent studies indicate that with samarium(III) iodide as the catalyst, indole derivatives can undergo regiospecifically 1,4-addition to α,β-unsaturated *N*-acylbenzotriazoles at their 3-position rather than being acylated.[15] In continuation of our previous study concerning the reactions between amines and *N*-cinnamoylbenzotriazoles,[13] here we present exhaustively the versatile addition reactions of α,β-unsaturated *N*-acylbenzotriazoles with different amino-containing compounds, such as aromatic amines, aliphatic amines, *o*-phenylenediamine, and *o*-aminothiophenol.

2. Results and discussion

2.1. The reaction between aromatic amines and *N*-cinnamoylbenzotriazoles

As mentioned above, *N*-acylbenzotriazoles are highly efficient *N*-acylating agents. Both aromatic and aliphatic amines have thus been acylated with these agents under neutral conditions to produce various amides in very good to excellent yields.[16] Also, Katritzky et al. reported recently that a variety of *N*-acylbenzotriazoles including *N*-cinnamoylbenzotriazoles could be coupled with either aromatic or aliphatic amines to form amides efficiently under microwave conditions.[17] However, when a mixture of aniline and *N*-cinnamoylbenzotriazole **2a** was refluxed in anhydrous THF in the presence of triethylamine, as shown in Scheme 1, a new product was obtained, which was previously characterized as β-amino *N*-acylbenzotriazole **3′aa** resulting from a normal aza-Michael addition (1,4-addition) of aniline to **2a**.[13] Surprisingly, in our subsequent studies it was found that no reaction could occur between the alleged β-amino *N*-acylbenzotriazole **3′aa** and primary amines under a variety of Lewis acid or base promoted conditions. Its failure to act as an acylating reagent as common *N*-acylbenzotriazoles[9] made us reconsider the structure of the product as **3′aa**′s regioisomer **3aa**.



Scheme 1.

Although three doublet–doublet peaks, which were characteristic of the aza-Michael addition product, were well observed in the ^{1}H NMR spectrum, the chemical shift of the proton in the β-position was 6.4 ppm, which seemed too much for an ordinary amine-mediated Michael addition product, whose β-H chemical shift usually locates at around 4.5 ppm.[3,4a–e,8] In a research carried out by Gandelman and Jacobsen,[4f] the products resulting from the conjugate addition of benzotriazole to *N*-Bz protected cinnamide followed by conversion into the β-benzotriazolyl esters showed a doublet–doublet peak at around 6.3–6.5 ppm in the ^{1}H NMR spectrum for the β-hydrogen. The linkage of benzotriazolyl heterocyclic nitrogen to the β-position arousing a migration of β-hydrogen absorption to the lower magnetic field gave us a hint that the product we isolated may have a β-benzotriazolyl structure. Also, the broad peak at around 8.0 ppm indicates that there may exist an amide N–H instead of an amine N–H. Single-crystal X-ray diffraction analysis[18] was further made for the product and the structure was unambiguously ascertained to be **3aa** (Fig. 1), substantiating the above considerations.

Compound **3aa**, from the synthetic design point, may be normally prepared from the aza-Michael addition of benzotriazole to *N*-phenylcinnamide. And correspondingly, its formation in this case could be conveniently explained as through N-acylation of aniline followed by Michael addition of the released benzotriazolyl to the in situ-formed *N*-phenylcinnamide. However, when a mixture of *N*-phenylcinnamide and benzotriazole was refluxed in THF under the same conditions, no reaction occurred at all (Scheme 2). Although the mechanism remains to be further explored, it was reasonable to deduce that the addition of benzotriazolyl may occur intramolecularly in a concerted process before it cleaved away.

Other base, stronger than triethylamine, such as DBU, was also examined as a promoter for the production of **3aa**, only to find that cinnamide as a co-product was formed in considerable amount (32%, isolated yield) besides the desired **3aa** (48%, isolated yield).

Therefore, with compound **3aa** as a sole product and isolated in very good yield (73%) promoted by triethylamine, further investigations have then been carried out under the conditions and the results are summarized in Table 1. Again, aniline reacted smoothly with *N*-cinnamoylbenzotriazoles **2b** and **2c** giving rise to the products **3ab** and **3ac** in good yields (Table 1, entries 2 and 3). The reactions between other aromatic amines, such as *p*,*m*,*o*-toluidine, 1-naphthylamine, *p*-chlorobenzenamine,

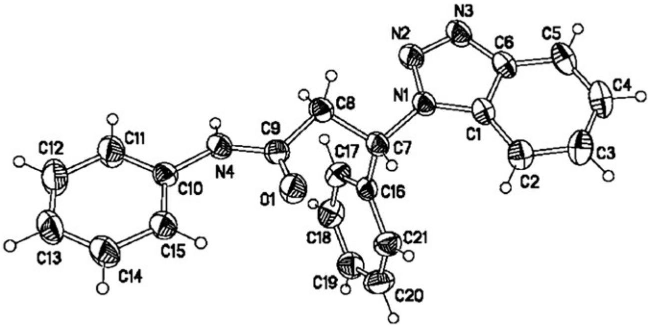
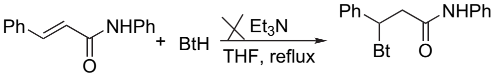


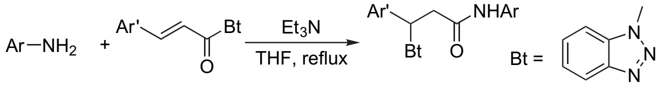
Figure 1. The crystal structure of **3aa**.



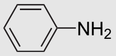
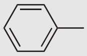
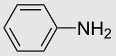
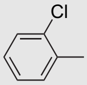
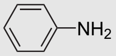
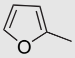
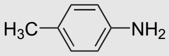
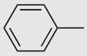
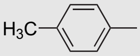
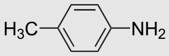
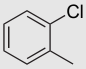
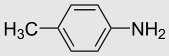
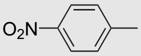
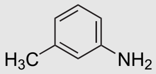
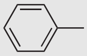
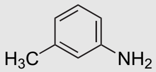
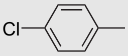
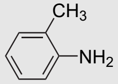
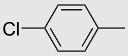
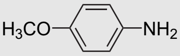
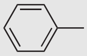
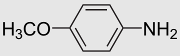
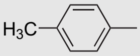
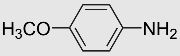
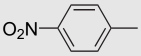
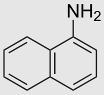
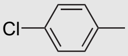
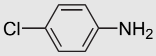
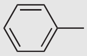
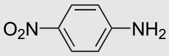
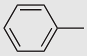
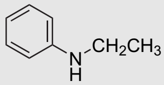
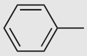
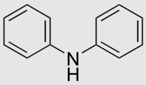
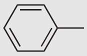
3aa

Scheme 2.

Table 1
The formation of β-benzotriazolyl amide **3** from aromatic amines and *N*-cinnamoylbenzotriazoles



1 **2** **3**

Entry	Aromatic amines **1**	Ar′ of **2**	Products **3**	Reaction time (h)	Yield[a] (%)
1	 **1a**	 **2a**	**3aa**	18	73
2	 **1a**	 **2b**	**3ab**	18	68
3	 **1a**	 **2c**	**3ac**	18	52
4	 **1b**	 **2a**	**3ba**	18	75
5	 **1b**	 **2d**	**3bd**	18	81
6	 **1b**	 **2b**	**3bb**	10	67
7	 **1b**	 **2e**	**3be**	24	56
8	 **1c**	 **2a**	**3ca**	24	60
9	 **1c**	 **2f**	**3cf**	21	55
10	 **1d**	 **2f**	**3df**	18	76
11	 **1e**	 **2a**	**3ea**	18	4 (56)[b]
12	 **1e**	 **2d**	**3ed**	18	21 (37)[b]
13	 **1e**	 **2e**	**3ee**	18	72 (—)[c]
14	 **1f**	 **2f**	**3ff**	18	70
15	 **1g**	 **2a**	**3ga**	24	65
16	 **1h**	 **2a**	—	36	—[d]
17	 **1i**	 **2a**	—	36	—[d]
18	 **1j**	 **2a**	—	36	—[d]

[a] Isolated yields based on *N*-cinnamoylbenzotriazoles.

[b] An inseparable mixture of 1,4- and 1,2-adduct was obtained as shown by the ^1H NMR. The yields of the 1,2-adducts are shown in parentheses.

[c] The byproduct was not isolated due to its trace amount but detected by TLC.

[d] No reaction.

p-anisidine, *p*-nitroaniline, *N*-ethylaniline, and *N*-phenylaniline, and different *N*-cinnamoylbenzotriazole derivatives were also investigated in order to widen the range and nature of the substituents on the aromatic ring. As expected, most reactions proceeded smoothly and led to products **3** in good to high yields (Table 1, entries 4–10, 14, and 15). It bears noting that under the present conditions both unsubstituted aromatic amines, like **1f**, and substituted aromatic amines with either a weak electron-donating group like **1b**–**d** or a weak electron-withdrawing group like **1g** could react well with various *N*-cinnamoylbenzotriazoles.

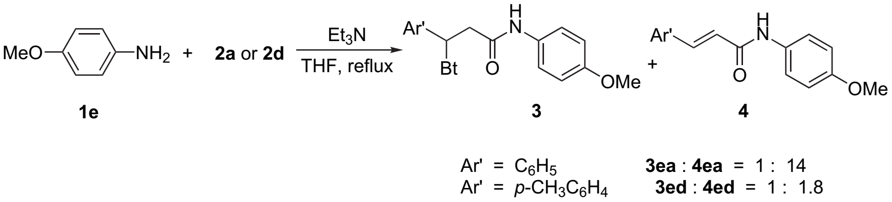
However, the reaction mode varied when *p*-anisidine **1e** was used (Table 1, entries 11–13). Reaction of **1e** with **2a** gave only a small amount of the expected **3ea** and predominantly the acylation product **4ea** in a 1:14 ratio, as shown in Scheme 3. Lower selectivity in favor of 1,2-addition was also observed in the coupling of **1e** and **2d**. However, anisidine **1e** reacted with *N*-cinnamoylbenzotriazole **2e** under the same conditions to give **3ee** in very good yield (72%). In addition, the coupling of *p*-nitroaniline and *N*-cinnamoylbenzotriazole failed to provide any product even after prolonged reaction times, as shown in entry 16 in Table 1, which might be caused by the low nucleophilicity of *p*-nitroaniline. Also, no coupling took place under the same conditions between either *N*-ethylaniline or *N*-phenylaniline and **2a** due presumably to their weakened nucleophilicity (Table 1, entries 17 and 18).

2.2. The reaction between aliphatic amines and *N*-crotonoylbenzotriazole

To obtain more information on the reactions between amines and α,β-unsaturated *N*-acylbenzotriazoles, we then turned to use α,β-unsaturated aliphatic *N*-acylbenzotriazoles as electrophilic agents. Interestingly, under the same mild conditions, reaction of aliphatic amines such as piperidine, phenethylamine, *n*-butylamine, and diethylamine with **2h** also afforded the corresponding β-benzotriazolyl amides **3** in very good yields at room temperature under solvent-free conditions even within shorter time (Table 2). The β-H chemical shift in the ^1H NMR spectra of **3oh**, **3lh**, **3nh**, and **3qh** all appeared at around 5.5 ppm, with migration to the lower magnetic field observed again. The attribution was also consistent with that of the β-benzotriazolyl imides resulting from the addition of benzotriazole to α,β-unsaturated aliphatic imides.[4f] In addition, *p*-toluidine was used as a nucleophile to react with **3lh**. Not surprisingly, the reaction failed to produce any product, which proved that **3lh**, instead of aliphatic amine-mediated aza-Michael addition product, was the compound formed here. The same ^1H NMR spectral pattern of **3oh**, **3nh**, and **3qh** made the determination of their structures equally reasonable.

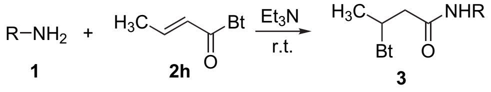
2.3. The Michael addition of aromatic amines to α,β-unsaturated aliphatic *N*-acylbenzotriazoles

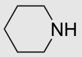
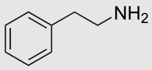
Exposure of *N*-crotonoylbenzotriazole **2h** to *p*-toluidine and Et_3N in THF led smoothly to the normal 1,4-adduct within 2.5 h and **5bh** was isolated in very good yield (75%). *p*-Anisidine could also react readily with **2h** in 1,4-attack mode affording **5eh** in good yield (62%). Both of the reactions proceeded at room temperature and completed within a few hours. In addition, α,β-unsaturated aliphatic *N*-acylbenzotriazole **2i** derived from α-methyl acrylic acid was also treated with aromatic amines **1b**, **1g**, and **1c**, respectively, and expectedly, the aza-Michael addition products **5bi**, **5gi**, and **5ci** were all produced in very good yields (Table 3, entries 3–5). The characterization as the products **5** instead of the type **3** compounds was based upon their β-H chemical shift at around 4.2–4.5 ppm in



Scheme 3. Reaction of *p*-anisidine with *N*-cinnamoylbenzotriazoles **2a** and **2d**.

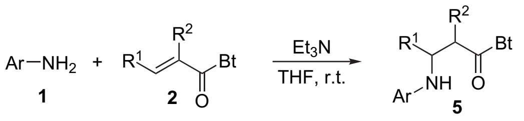
Table 2
The formation of β-benzotriazolyl amide from aliphatic amines and *N*-crotonoylbenzotriazole

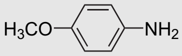
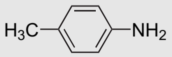
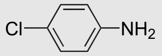
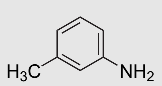


Entry	Amine		R¹		R²	Product	Reaction time (min)	Yields[a] (%)
1		**1o**	CH_3–	**2h**	H	**3oh**	5	80
2		**1l**	CH_3–	**2h**	H	**3lh**	5	85
3	n-$C_4H_9NH_2$	**1n**	CH_3–	**2h**	H	**3nh**	5	82
4	$(C_2H_5)_2NH$	**1q**	CH_3–	**2h**	H	**3qh**	5	80

[a] Isolated yields based on α,β-unsaturated aliphatic *N*-acylbenzotriazoles.

Table 3
The Michael addition of aromatic amines to α,β-unsaturated aliphatic *N*-acylbenzotriazoles



Entry	Amine		R¹		R²	Product	Reaction time (h)	Yields[a] (%)
1		**1b**	CH_3–	**2h**	H	**5bh**	2.5	75
2		**1e**	CH_3–	**2h**	H	**5eh**	4	62
3		**1b**	H	**2i**	CH_3	**5bi**	3.5	80
4		**1g**	H	**2i**	CH_3	**5gi**	4.5	82
5		**1c**	H	**2i**	CH_3	**5ci**	5	82

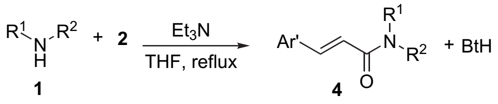
[a] Isolated yields based on α,β-unsaturated aliphatic *N*-acylbenzotriazoles.

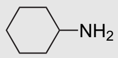
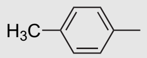
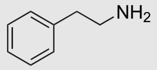
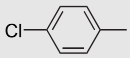
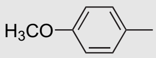
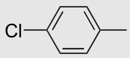
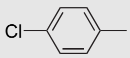
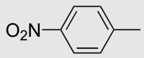
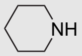
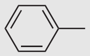
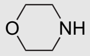
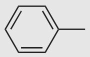
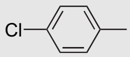
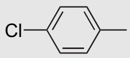
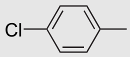
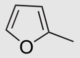
the ^{1}H NMR spectra. Besides, product **5ci** could, to our anticipation, acylate *p*-anisidine smoothly and afforded the corresponding amide **6** (Scheme 4), indicating that the *N*-acylbenzotriazole structure was included in compounds **5**.

2.4. The acylation of aliphatic amines with *N*-cinnamoylbenzotriazoles

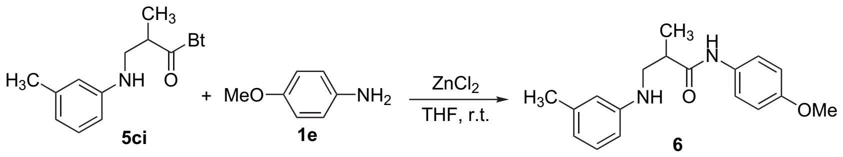
Although most aromatic amines readily reacted with α,β-unsaturated *N*-acylbenzotriazole derivatives affording either the novel addition or the normal aza-Michael addition products as

Table 4
The acylation (1,2-addition) of aliphatic amines with *N*-cinnamoylbenzotriazoles

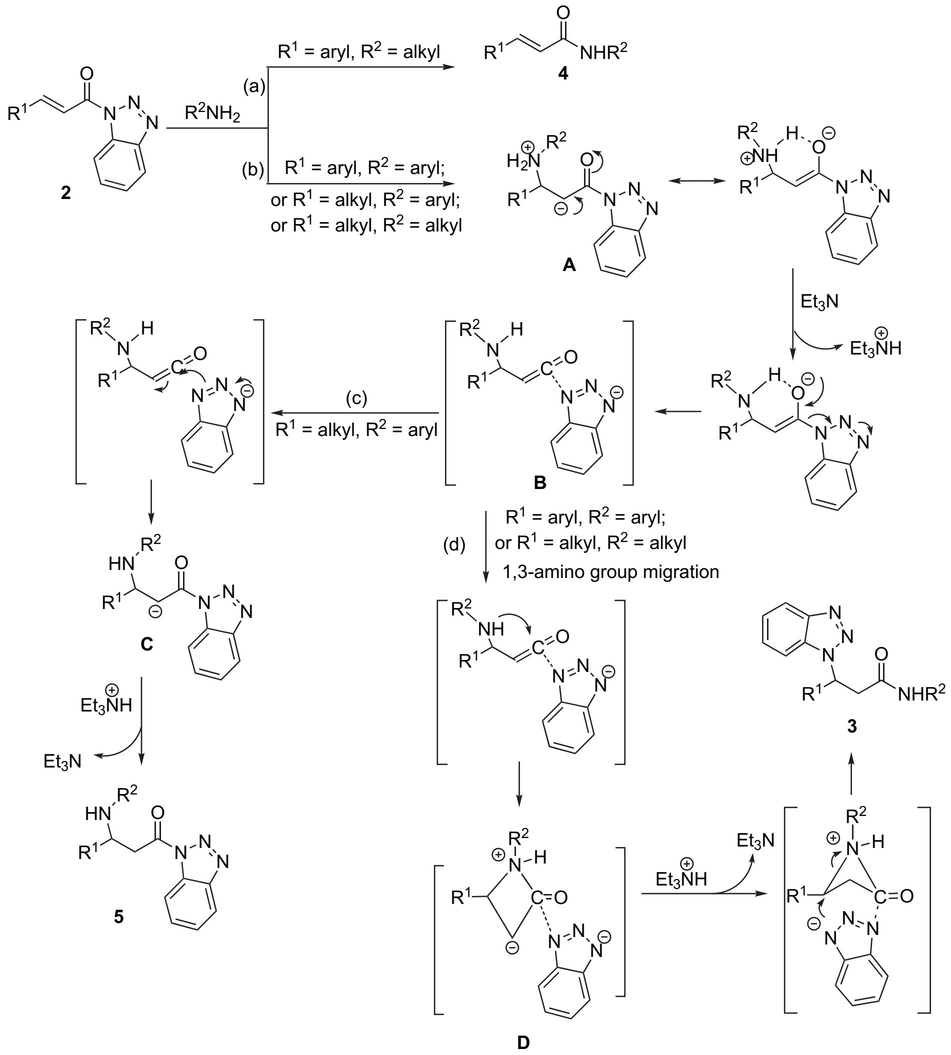


Entry	Alkyl amines **1**		Ar′ of **2**		Product	Reaction	Yield[a] (%)
1		**1k**		**2d**	**4kd**	6 h	91
2		**1l**		**2f**	**4lf**	2.5 h	86
3	n-$C_3H_7NH_2$	**1m**		**2g**	**4mg**	1.5 h	91
4	n-$C_4H_9NH_2$	**1n**		**2f**	**4nf**	10 min	95
5	n-$C_4H_9NH_2$	**1n**		**2f**	**4nf**	30 min[b]	95
6	n-$C_3H_7NH_2$	**1m**		**2e**	**4me**	10 min[b]	95
7		**1o**		**2a**	**4oa**	3 h	88
8		**1p**		**2a**	**4pa**	3 h	83
9	$(C_2H_5)_2NH$	**1q**		**2f**	**4qf**	3 h	80
10	$(C_2H_5)_2NH$	**1q**		**2f**	**4qf**	24 h	82[c]
11	$(C_2H_5)_2NH$	**1q**		**2f**	**4qf**	24 h	85[d]
12	$(C_2H_5)_2NH$	**1q**		**2c**	**4qc**	1.5 h	87

[a] Isolated yields based on *N*-cinnamoylbenzotriazoles.
[b] Carried out at room temperature.
[c] Prolonging the reaction to comparable time did not afford any detectable amount of type **3** compounds.
[d] Diethylamine (2.2 equiv) was used.



Scheme 4. The acylation of *p*-anisidine with aza-Michael product **5ci**.



Scheme 5. Proposed routes for the formation of compounds **3**–**5**.

described above, to our surprise, when cyclohexylamine, an aliphatic amine, was treated with *N*-cinnamoylbenzotriazole **2d** in the presence of Et_3N, the corresponding cinnamide **4kd** was isolated in excellent yield (91%) (Table 4, entry 1). Apparently, this product was generated through 1,2-attack of cyclohexylamine to the *N*-cinnamoylbenzotriazole. In order to further explore the scope of this reaction, we proceeded to use various aliphatic amines **1l**–**q** as the nucleophiles, as outlined in Table 4.

Interestingly, all the primary and secondary aliphatic amines in Table 4 gave solely the acylation products by reaction with different *N*-cinnamoylbenzotriazole derivatives in high to excellent yields (80–95%). For instance, reaction of phenethylamine **1l** with *N*-cinnamoylbenzotriazole **2f** under the above described conditions led to the α,β-unsaturated amide **4lf** in 86% yield (Table 4, entry 2). Similarly, acylation of diethylamine **1q** with *N*-cinnamoylbenzotriazoles **2f** and **2c** in THF and in the presence of Et_3N also proceeded smoothly to give the corresponding amides **4qf** and **4qc** in 80% and 87% yields, respectively (Table 4, entries 9 and 12). It is worth mentioning that only cinnamides **4** was formed exclusively even after prolonging the reaction time to 24 h (Table 4, entry 10), suggesting once again that the released benzotriazoyl did not undergo further aza-Michael addition to the in situ-formed **4** to afford type **3** compounds. Diethylamine, a stronger nucleophile than benzotriazole, was used in excessive amount (Table 4, entry 11), but further aza-Michael addition of diethylamine to cinnamide **4qf** could not be observed either.

2.5. Mechanism discussion for the formation of compounds 3–5

As could be summarized from the above results, the versatile reactions presented are interesting and can offer useful methods for the preparation of β-benzotriazolyl amide **3** (could not be prepared from routine aza-Michael addition), α,β-unsaturated amides **4** (by avoidance of using moisture sensitive α,β-unsaturated acyl chlorides here), and β-amino *N*-acylbenzotriazoles **5** (useful intermediates for β-amino acid derivatives).

Although a thorough mechanistic investigation is pending, the discrimination of aromatic and aliphatic amines by *N*-cinnamoylbenzotriazoles and α,β-unsaturated aliphatic *N*-acylbenzotriazoles may be tentatively rationalized based on the hard–soft acid–base (HSAB) theory and steric effect. Aliphatic amines tend to be hard bases with the unshared electron localized intensely on the nitrogen atom itself. As such, they attacked predominantly the hard acid position, i.e., the 2-position of *N*-cinnamoylbenzotriazole (the carbonyl carbon), thereby giving rise to cinnamides **4** (Scheme 5, route a). Also, the relatively bulky aryl group at the 4-position of

N-cinnamoylbenzotriazoles disfavored the Michael addition, which could also account for the observed 1,2-addition.

Aromatic amines behave more like soft bases since the unshared electron of the nitrogen atom can delocalize to the phenyl ring. They are thus prone to attack the soft acid center (the 4-positon of α,β-unsaturated *N*-acylbenzotriazoles, the olefinic carbon). In other words, the aza-Michael addition was favored for aromatic amines (Scheme 5, route b). However, the observed aza-Michael addition of aliphatic amines to *N*-crotonoylbenzotriazole (R^1=R^2=alkyl) (Scheme 5, route b) may be attributed to the decreased steric hindrance of the 4-position of the α,β-unsaturated systems and the steric effect may thus exert predominant influence in this case.

Benzotriazolyl group is a good leaving group, therefore, it is possible for the Michael addition intermediate **A** to transform into the ketene intermediate **B**, in which the ketene forms contact ion pair with the benzotriazole anion. A subsequent intramolecular amino attack could take place giving a four-membered cyclic intermediate **D**,[19] as shown in route d of Scheme 5. In other words, the above aza-Michael addition products could undergo in situ rearrangement via the **D**-like intermediates to form the product **3**. In this respect, the more nucleophilic aliphatic amines could migrate more readily,[20] so when R^2 is an alkyl, the rearrangement would be more favorable than the cases where R^2 is an aryl group. However, it should be noted that the aryl substituent of R^1 in intermediate **B** could also facilitate the arylamino group (when R^2=aryl) migration since in those cases cleavage of a benzylic C–N bond would be involved. In addition, when R^1 in intermediate **B** is an alkyl group, the aryl assistance does not exist and the migration of the less nucleophilic aromatic amino group does not occur. Hence, the reaction could proceed in a different way, as shown in route c of Scheme 5, in which the benzotriazole anion attacks the carbonyl carbon resulting in the formation of the normal Michael addition product **5** through intermediate **C**.

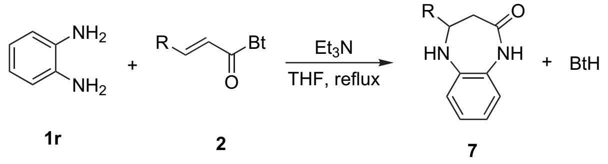
2.6. Synthesis of heterocycles from *o*-phenylenediamine and α,β-unsaturated *N*-acylbenzotriazoles

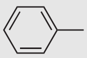
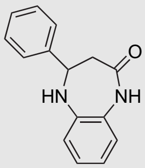
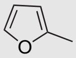
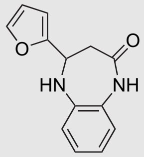
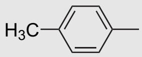
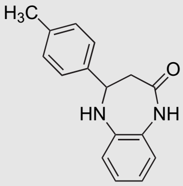
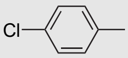
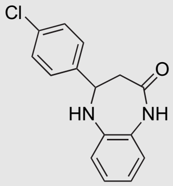
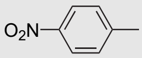
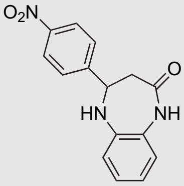
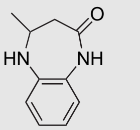
Encouraged by the above results, our attention then turned toward applying the procedure to the construction of heterocycles. To test the feasibility of this strategy, we first chose *o*-phenylenediamine **1r** as the nucleophile to react with a series of α,β-unsaturated *N*-acylbenzotriazoles, as listed in Table 4. Reaction of **1r** with *N*-cinnamoylbenzotriazole **2a** in the presence of Et$_3$N in THF gave, fortunately, the desired product **7ra** in high yield (85%). By the same procedure, heterocycles **7rc**–**e** were also efficiently prepared from **1r** and the corresponding *N*-cinnamoylbenzotriazoles **2c**–**e** in 76%, 76%, 81%, and 83% yields, respectively (Table 5, entries 2–5). Similarly, the amino groups in **1r** can also be ring-closed by its transformation with *N*-crotonoylbenzotriazole **2h** to the 1,3,4,5-tetrahydro-4-methyl-1,5-benzodiazepine-2-one **7rh** in 80% yield. It should be mentioned here that the 1,5-benzodiazepine ring is often encountered in biologically active natural products as well as drug candidates,[21] thus the compounds synthesized in Table 5 could be potential bioactive agents. Therefore, these smooth reactions, together with the following reactions (as seen in Table 6), provided a convenient access to biologically interesting heterocycles, which can be used for further chemical manipulation or biological screening.

It could be concluded from our experimental results that with two nucleophilic sites available in the same nucleophilic agent, the Michael addition and acylation reaction of α,β-unsaturated *N*-acylbenzotriazoles could proceed concurrently to generate interesting cyclized products. In other words, Michael addition of α,β-unsaturated *N*-acylbenzotriazoles could be accompanied or followed by immediate acylation in the same reaction, or vice versa.

Table 5

Synthesis of 1,3,4,5-tetrahydro-4-substituted-1,5-benzodiazepine-2-ones **7**



Entry	R of **2**		Product		Reaction time (h)	Yield[a] (%)
1		**2a**		**7ra**	12	85
2		**2c**		**7rc**	12	76
3		**2d**		7**rd**	12	76
4		**2f**		**7rf**	10	81
5		**2e**		**7re**	2	83
6	CH$_3$–	**2h**		**7rh**	2.5	80

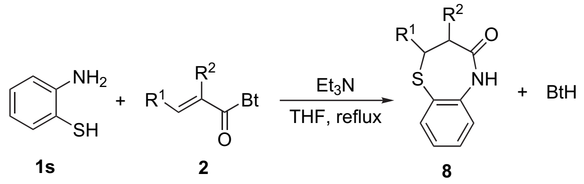
[a] Isolated yields based on α,β-unsaturated *N*-acylbenzotriazoles.

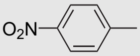
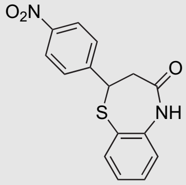
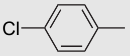
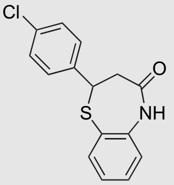
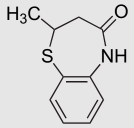
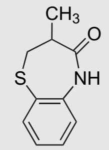
2.7. Synthesis of heterocycles from *o*-aminothiophenol and α,β-unsaturated *N*-acylbenzotriazoles

The ready formation of 1,5-benzodiazepine derivatives suggested that the present strategy could also be practicable for the synthesis of other different heterocycles. Hence, *o*-aminothiophenol **1s** was chosen as another nucleophile to react with several α,β-unsaturated *N*-acylbenzotriazoles. The results are summarized in Table 6. As expected, all the reactions worked well

Table 6

Synthesis of 2,3-dihydrobenzo[*b*][1,4]thiazepin-4(5*H*)-ones **8**.



Entry	R^1		R^2	Products		Reaction time (h)	Yield[a] (%)
1		**2e**	H		**8se**	10	69
2		**2f**	H		**8sf**	10	70
3	CH_3--	**2h**	H		**8sh**	10	70
4	H	**2i**	CH_3		**8si**	4	78

[a] Isolated yields based on α,β-unsaturated *N*-acylbenzotriazoles.

under the same conditions and led to the desired 2,3-dihydrobenzo[*b*][1,4]thiazepin-4(5*H*)-ones **8se**, **8sf**, **8sh**, and **8si** in very good yields (69–78%), in which the sulfhydryl group of the nucleophile attacked the 4-position of α,β-unsaturated *N*-acylbenzotriazoles while the amino group attacked the 2-position. The resulting seven-membered *N*,*S*-heterocycle derivatives were characterized on the basis of their exact mass spectrometries and their NMR spectroscopic data, which exhibited signals between δ 171 and 173 ppm in the ^{13}C NMR spectra for the amide carbons. The chemical shift was in agreement with the literature values for this type of heterocycles,[22] which have ^{13}C NMR chemical shift at 176–179 ppm for the amide carbons. On the other hand, alternative attack of *o*-aminothiophenol, i.e., the sulfhydryl group attacking 2-position whereas the amino group attacking 4-position of α,β-unsaturated *N*-acylbenzotriazoles, would have led to thioester functionality, which has ^{13}C NMR chemical shift at much lower field (~190 ppm). Apparently, our data indicated clearly the formation of benzothiazepin derivatives **8**.

It is worth mentioning here that aromatic ring-fused 1,4-thiazepine derivatives represent an important group of compounds possessing biologically interesting properties.[23] Although 2,3-dihydrobenzo[*b*][1,4]thiazepin-4(5*H*)-one scaffold has been constructed previously from *o*-aminothiophenol and cinnamates, two separate steps were needed and the cyclization step had to be carried out either under relatively harsh conditions or using Me_3Al as the reagent.[24]

3. Conclusion

In summary, we have studied systematically the nucleophilic additions of α,β-unsaturated *N*-acylbenzotriazoles with aromatic amines and aliphatic amines, and observed versatile reactions. α,β-Unsaturated *N*-acylbenzotriazoles have been demonstrated to be useful in the preparation of β-benzotriazolyl amides, β-amino *N*-acylbenzotriazoles, and cinnamides depending on the type of α,β-unsaturated *N*-acylbenzotriazoles and amines used. Furthermore, the concurrent 1,4- and 1,2-addition of α,β-unsaturated *N*-acylbenzotriazoles with binucleophiles, *o*-phenylenediamine and *o*-aminothiophenol, was also investigated and the corresponding biologically interesting seven-membered heterocycles were successfully constructed.

4. Experimental section

4.1. General information

THF was distilled from sodium–benzophenone. Flash chromatography was performed with the indicated solvent system using 30–60 μm silica gel. The melting points were uncorrected. ^1H NMR spectra were recorded with 400 MHz instrument using tetramethylsilane as an internal standard, while ^{13}C NMR spectra were recorded at 100 MHz. High-resolution mass spectra were measured at UCD, Ireland on a Micromass Quattro. IR spectra were recorded in film or using KBr disks with a NEXUS 670 FTIR spectrometer. Mass spectra were recorded on an HP 5989B MS spectrometer. Elemental analyses were performed on a Vario-ELIII instrument. α,β-Unsaturated *N*-acylbenzotriazoles were prepared by following the literature procedure.[10,25]

4.2. General procedure for the novel addition of aromatic amines to *N*-cinnamoylbenzotriazoles (Table 1)

To a stirred solution of the appropriate *N*-cinnamoylbenzotriazole (1 mmol) and the corresponding aromatic amine (1.1 mmol) in THF (10 mL) was added triethylamine (1 mL). The resulting mixture was refluxed until the disappearance of the *N*-cinnamoylbenzotriazole, as determined by TLC (typically 18–24 h). At this time, the mixture was concentrated under reduced pressure to give a residue, which was then purified by flash column chromatography (cyclohexane–EtOAc) to afford the corresponding β-benzotriazolyl amide **3**.

*4.2.1. 3-(1H-Benzo[d][1,2,3]triazol-1-yl)-N-3-diphenylpropanamide (**3aa**)*

Mp 167–169 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J*=8.2 Hz, 1H, ArH), 7.97 (br s, 1H, CONH), 7.46–7.23 (m, 12H, ArH), 7.06–7.03 (m, 1H, ArH), 6.45 (dd, *J*=5.2, 10.0 Hz, 1H, H-3), 4.09 (dd, *J*=10.0, 15.2 Hz, 1H, H-2a), 3.46 (dd, *J*=5.20, 15.2 Hz, 1H, H-2b); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.5, 146.0, 138.7, 137.7, 129.1, 129.0, 128.9, 128.6, 127.7, 126.6, 124.5, 124.4, 120.2, 119.6, 110.1, 56.0, 43.6; IR ν_{max} (KBr) 3299 (NH), 3257, 3138, 3085, 1682 (C=O), 1602 cm^{-1}; EIMS *m*/*z* (%) 342 (0.8, M^+), 341 (2.1, M^+-1), 266 (3.2, M^+-Ph+1), 237 (6.1), 223 (5.5), 118 (100, Bt); ESI-HRMS calcd for $C_{21}H_{19}N_4O$ $[M+H]^+$ 343.1559, found 343.1555.

*4.2.2. 3-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-(2-chlorophenyl)-N-phenylpropan-amide (**3ab**)*

Mp 179–180 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 8.30 (br s, 1H, CONH), 8.00 (d, *J*=8.4 Hz, 1H, ArH), 7.56–7.34 (m, 6H, ArH), 7.22–7.02 (m, 7H), 4.06 (dd, *J*=10.0, 15.2 Hz, 1H, H-2a), 3.50 (dd,

J=4.4, 15.2 Hz, 1H, H-2b); ^{13}C NMR (100 MHz, CDCl$_3$) δ 166.9, 146.0, 136.2, 133.3, 132.4, 130.0, 129.8, 128.9, 128.0, 127.9, 127.7, 124.5, 124.4, 120.0, 119.7, 110.1, 110.0, 56.1, 42.2; IR $\nu_{\max}$ (KBr) 3274 (NH), 3065, 1687 (C=O), 1599 cm^{-1}; ESI-HRMS calcd for C$_{21}$H$_{18}$N$_4$OCl [M+H]$^+$ 377.1169, found 377.1185.

4.2.3. *3-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-(furan-2-yl)-N-phenylpropanamide (**3ac**)*

Mp 193–195 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.50 (br s, 1H, CONH), 8.02 (t, J=8.4 Hz, 1H, ArH), 7.69 (d, J=8.4 Hz, 1H, ArH), 7.51–7.22 (m, 7H, ArH), 7.08–7.04 (m, 1H, ArH), 6.62–6.61 (m, 1H, H-3), 6.37–6.35 (m, 1H, ArH), 6.29–6.26 (m, 1H, ArH), 4.62–3.95 (m, 1H, H-2a), 3.74 (dd, J=5.6, 15.2 Hz, 1H, H-2b); ^{13}C NMR (100 MHz, CDCl$_3$) δ 167.2, 151.3, 145.6, 144.0, 139.2, 133.0, 129.2, 127.9, 124.6, 123.8, 119.7, 119.5, 111.3, 111.1, 108.9, 52.9, 39.0; IR $\nu_{\max}$ (KBr) 3309 (NH), 3271, 2918, 2853, 1685 (C=O), 1602, 1544 cm^{-1}; EIMS m/z (%) 332 (5.8, M$^+$), 331 (19.4, M$^+$−1), 213 (7.8), 170 (21.8), 118 (100, Bt); ESI-HRMS calcd for C$_{19}$H$_{17}$N$_4$O$_2$ [M+H]$^+$ 333.1352, found 333.1344.

4.2.4. *3-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-phenyl-N-p-tolylpropanamide (**3ba**)*

Mp 207–209 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.42 (br s, 1H, CONH), 8.00 (d, J=8.0 Hz, 1H, ArH), 7.51–7.26 (m, 10H, ArH), 7.03 (d, J=8.0 Hz, 2H, ArH), 6.48 (dd, J=5.6, 8.8 Hz, 1H, CH, H-3), 4.10 (dd, J=9.2, 15.2 Hz, 1H, CH, H-2a), 3.60 (dd, J=5.6, 15.2 Hz, 1H, CH, H-2b), 2.26 (s, 3H, Me); ^{13}C NMR (100 MHz, CDCl$_3$) δ 167.2, 146.1, 138.7, 134.9, 134.2, 133.2, 129.4, 129.1, 128.6, 127.6, 126.5, 124.3, 120.2, 119.8, 110.0, 60.0, 43.9, 20.8; IR $\nu_{\max}$ (KBr) 3303 (NH), 3267, 3197, 3127, 3066, 1683 (C=O), 1603, 1542 cm^{-1}; ESI-HRMS calcd for C$_{22}$H$_{21}$N$_4$O [M+H]$^+$ 357.1715, found 357.1702.

4.2.5. *3-(1H-Benzo[d][1,2,3]triazol-1-yl)-N-3-di-p-tolylpropanamide (**3bd**)*

Mp 174–176 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.37 (br s, 1H, CONH), 8.00 (d, J=4.0 Hz, 1H, ArH), 7.50–7.48 (m, 1H, ArH), 7.43–7.39 (m, 1H, ArH), 7.34–7.24 (m, 5H, ArH), 7.09–7.02 (m, 4H, ArH), 6.43 (dd, J=4.0, 8.0 Hz, 1H, H-3), 4.06 (dd, J=4.0, 8.0 Hz, 1H, H-2a), 3.54 (dd, J=4.0, 7.6 Hz, 1H, H−2b), 2.27 (s, 3H, Me), 2.26 (s, 3H, Me); ^{13}C NMR (100 MHz, CDCl$_3$) δ 167.5, 145.9, 138.4, 135.7, 135.4, 133.9, 133.2, 129.7, 129.3, 127.6, 126.6, 124.4, 120.2, 119.5, 110.2, 59.8, 43.4, 21.1, 20.8; IR $\nu_{\max}$ (KBr) 3309 (NH), 3271, 3131, 3072, 1686 (C=O), 1608 cm^{-1}; EIMS m/z (%) 369 (9.4, M$^+$−1), 212 (4.3), 118 (100, Bt); ESI-HRMS calcd for C$_{23}$H$_{23}$N$_4$O [M+H]$^+$ 371.1872, found 371.1868.

4.2.6. *3-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-(2-chlorophenyl)-N-p-tolylpropanamide (**3bb**)*

Mp 205–207 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.01 (d, J=8.4 Hz, 1H, ArH), 7.95 (br s, 1H, CONH), 7.55 (d, J=8.0 Hz, 1H, ArH), 7.43–7.42 (m, 2H, ArH), 7.34 (t, J=8.0 Hz, 1H, ArH), 7.27–7.12 (m, 5H, ArH), 7.03–6.98 (m, 3H), 4.00 (dd, J=10.8, 14.8 Hz, 1H, H-2a), 3.44 (dd, J=13.2, 25.6 Hz, 1H, H-2b), 2.25 (s, 3H, Me); ^{13}C NMR (100 MHz, CDCl$_3$) δ 166.8, 145.9, 136.2, 135.1, 134.0, 133.3, 132.5, 130.0, 129.8, 129.3, 128.0, 127.9, 127.7, 124.5, 120.1, 119.6, 110.2, 56.0, 42.1, 20.8; IR $\nu_{\max}$ (KBr) 3368 (NH), 3120, 1685(C=O), 1600, 1536 cm^{-1}; ESI-HRMS calcd for C$_{22}$H$_{20}$ClN$_4$O [M+H]$^+$ 391.1326, found 391.1320.

4.2.7. *3-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-(4-nitrophenyl)-N-p-tolylpropanamide (**3be**)*

Mp 184–186 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.75 (br s, 1H, CONH), 8.11 (d, J=8.0 Hz, 2H, ArH), 8.01 (d, J=8.0 Hz, 1H, ArH), 7.56–7.46 (m, 4H, ArH), 7.41–7.31 (m, 3H, ArH), 7.05 (d, J=8.0 Hz, 2H, ArH), 6.63 (dd, J=4.0, 4.0 Hz, 1H, H-3), 4.10 (dd, J=8.0, 16.0 Hz, 1H, H-2a), 3.77 (dd, J=4.0, 16.0 Hz, 1H, H-2b), 2.27 (s, 3H, Me); ^{13}C NMR (100 MHz, CDCl$_3$) δ 166.5, 147.9, 145.9, 145.4, 134.9, 134.5, 133.1, 129.5, 128.3, 127.8, 124.9, 124.3, 120.2, 119.8, 109.6, 58.9, 43.1, 20.9; IR $\nu_{\max}$ (KBr) 3122, 1668 (C=O), 1609 cm^{-1}; ESI-HRMS calcd for C$_{22}$H$_{20}$N$_5$O$_3$ [M+H]$^+$ 402.1566, found 402.1560.

4.2.8. *3-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-phenyl-N-m-tolylpropanamide (**3ca**)*

Mp 158–160 °C; ^{1}H NMR (400 MHz, DMSO) δ 10.13 (br s, 1H, CONH), 7.99 (d, J=8.0 Hz, 1H, ArH), 7.90 (d, J=8.0 Hz, 1H, ArH), 7.50–7.44 (m, 3H, ArH), 7.38–7.22 (m, 6H, ArH), 7.12 (t, J=8.0 Hz, 1H, ArH), 6.79 (d, J=7.2 Hz, 1H, ArH), 6.58 (dd, J=5.2, 10.0 Hz, 1H, H-3), 3.92 (dd, J=10.0, 15.6 Hz, 1H, H-2a), 3.49 (dd, J=5.2, 15.6 Hz, 1H, H-2b), 2.19 (s, 3H, Me); ^{13}C NMR (100 MHz, DMSO) δ 167.7, 145.7, 139.5, 139.3, 138.4, 133.2, 129.3, 129.0, 128.7, 127.9, 127.3, 124.7, 124.4, 119.9, 119.6, 116.6, 111.3, 58.9, 41.9, 21.6; IR $\nu_{\max}$ (KBr) 3140, 1681(C=O), 1614 cm^{-1}; ESI-HRMS calcd for C$_{22}$H$_{21}$N$_4$O [M+H]$^+$ 357.1715, found 357.1700.

4.2.9. *3-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-(4-chlorophenyl)-N-m-tolylpropanamide (**3cf**)*

Mp 173–175 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.90 (br s, 1H, CONH), 8.01 (d, J=8.4 Hz, 1H, ArH), 7.53 (d, J=8.4 Hz, 1H, ArH), 7.46–7.21 (m, 8H, ArH), 7.15–7.13 (m, 1H, ArH), 6.87 (d, J=7.2 Hz, 1H, ArH), 6.51 (dd, J=6.4, 8.0 Hz, 1H, H-2a), 4.09 (dd, J=8.4, 16.6 Hz, 1H, H-2b), 3.73 (dd, J=6.4, 15.2 Hz, 1H, CH), 2.26 (s, 3H, Me); ^{13}C NMR (100 MHz, CDCl$_3$) δ 167.2, 145.9, 138.8, 137.7, 137.1, 134.6, 133.1, 129.3, 128.7, 128.2, 127.9, 125.3, 124.7, 120.8, 119.6, 117.2, 110.0, 59.1, 43.3, 21.4; IR $\nu_{\max}$ (KBr) 3327 (NH), 1693 (C=O), 1590 cm^{-1}; ESI-HRMS calcd for C$_{22}$H$_{20}$ClN$_4$O [M+H]$^+$ 391.1326, found 391.1311.

4.2.10. *3-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-(4-chlorophenyl)-N-o-tolylpropanamide (**3df**)*

Mp 211–213 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.01 (d, J=8.4 Hz, 1H, ArH), 7.76 (br s, 1H, CONH), 7.49–7.42 (m, 3H, ArH), 7.36–7.26 (m, 5H, ArH), 7.12–7.10 (m, 2H, ArH), 7.06–7.04 (m, 1H, ArH), 6.42 (dd, J=5.2, 9.6 Hz, 1H, H-3), 4.05 (dd, J=5.6, 14.4 Hz, 1H, H-2a), 3.49 (dd, J=5.2, 14.4 Hz, 1H, H-2b), 2.05 (s, 3H, Me); ^{13}C NMR (100 MHz, CDCl$_3$) δ 167.2, 146.1, 137.1, 135.0, 134.7, 133.0, 130.6, 130.4, 129.4, 128.0, 127.9, 126.6, 125.8, 124.5, 123.8, 119.9, 109.8, 59.4, 43.6, 17.6; IR $\nu_{\max}$ (KBr) 3257 (NH), 3185, 3097, 1680 (C=O), 1600, 1521 cm^{-1}; ESI-HRMS calcd for C$_{22}$H$_{20}$ClN$_4$O [M+H]$^+$ 391.1326, found 391.1323.

4.2.11. *3-(1H-Benzo[d][1,2,3]triazol-1-yl)-N-(4-methoxyphenyl)-3-(4-nitrophenyl)propanamide (**3ee**)*

Mp 200–202 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.16 (d, J=8.8 Hz, 2H, ArH), 8.08 (br s, 1H, CONH), 8.05 (d, J=8.4 Hz, 1H, ArH), 7.54–7.34 (m, 5H, ArH), 7.30–7.26 (m, 2H, ArH), 6.79 (d, J=8.8 Hz, 2H, ArH), 6.59 (dd, J=5.6, 8.4 Hz, 1H, H-3), 4.04 (dd, J=8.8, 15.2 Hz, 1H, H-2a), 3.75 (s, 3H, Me), 3.58 (dd, J=6.0, 15.2 Hz, 1H, H-2b); ^{13}C NMR (100 MHz, CDCl$_3$) δ 166.3, 156.8, 145.5, 130.2, 128.2, 127.7, 124.8, 124.4, 122.1, 120.0, 114.2, 109.5, 59.0, 55.5, 43.3; IR $\nu_{\max}$ (KBr) 3245(NH), 3133, 2835, 1674 (C=O), 1607 cm^{-1}; ESI-HRMS calcd for C$_{22}$H$_{20}$N$_5$O$_4$ [M+H]$^+$ 418.1515, found 418.1533.

4.2.12. *3-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-(4-chlorophenyl)-N-(naphthalen-1-yl)propanamide (**3ff**)*

Mp 230–232 °C; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.23 (br s, 1H, CONH), 8.00 (d, J=8.0 Hz, 1H, ArH), 7.80 (d, J=8.0 Hz, 1H, ArH), 7.68 (d, J=8.0 Hz, 1H, ArH), 7.60 (d, J=8.0 Hz, 1H, ArH), 7.50 (d, J=8.0 Hz, 1H, ArH), 7.46–7.29 (m, 10H, ArH), 6.46 (dd, J=8.0, 16.0 Hz, 1H, H-3), 4.16 (dd, J=8.0, 16.0 Hz, 1H, H-2a), 3.67 (dd, J=8.0, 16.0 Hz, 1H, H-2b); ^{13}C NMR (100 MHz, CDCl$_3$) δ 168.0, 146.0, 137.1, 135.9, 135.2, 133.4, 131.7, 129.4, 128.5, 128.1, 127.9, 126.6, 126.5, 126.1, 125.5, 124.5, 121.4, 122.0, 121.1, 119.9, 109.8, 59.6, 43.7; IR $\nu_{\max}$ (KBr) 3220 (NH), 3061, 2963, 1680 (C=O), 1596, 1509 cm^{-1}; ESI-HRMS calcd for C$_{25}$H$_{20}$ClN$_4$O [M+H]$^+$ 427.1326, found 427.1327.

*4.2.13. 3-(1H-Benzo[d][1,2,3]triazol-1-yl)-N-(4-chlorophenyl)-3-phenylpropanamide (**3ga**)*

Mp decomposed beyond 219 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29 (br s, 1H, CONH), 8.01 (d, *J*=8.0 Hz, 1H, ArH), 7.55–7.26 (m, 11H, ArH), 7.19 (d, *J*=8.8 Hz, 1H, ArH), 6.43 (dd, *J*=5.2, 9.6 Hz, 1H, H-3), 4.11 (dd, *J*=9.6, 14.8 Hz, 1H, H-2a), 3.49 (dd, *J*=4.4, 14.8 Hz, 1H, H-2b); ^{13}C NMR (100 MHz, DMSO) δ 168.0, 145.7, 139.4, 138.2, 133.2, 129.3, 129.1, 128.8, 127.9, 127.3, 127.2, 124.7, 121.0, 120.0, 111.3, 58.8, 42.0. IR ν_{max} (KBr) 3262 (NH), 3193, 3123, 3063, 1684 (C=O), 1609, 1547 cm^{-1}; ESI-HRMS calcd for $C_{21}H_{18}ClN_4O$ $[M+H]^+$ 377.1169, found 377.1151.

4.3. General procedure for the novel addition of aliphatic amines to *N*-crotonoyl benzotriazoles (Table 2)

N-Crotonoylbenzotriazole (1 mmol) and the corresponding aliphatic amine (1.1 mmol) were mixed and stirred at room temperature. After completion of the reaction in 5 min as determined by TLC, the reaction mixture was directly purified by flash column chromatography (cyclohexane–EtOAc) to afford the corresponding β-benzotriazolyl amide **3**.

*4.3.1. 3-(1H-Benzo[d][1,2,3]triazol-1-yl)-1-(piperidin-1-yl)butan-1-one (**3oh**)*

Oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (d, *J*=8.4 Hz, 1H, ArH), 7.66 (d, *J*=8.4 Hz, 1H, ArH), 7.48 (t, *J*=7.6 Hz, 1H, ArH), 7.35 (t, *J*=7.6 Hz, 1H, ArH), 5.52–5.47 (m, 1H, H-3), 3.43–3.29 (m, 5H), 2.96 (dd, *J*=6.0, 16.0 Hz, H-2b), 1.76 (d, *J*=6.8 Hz, 3H, Me), 1.57–1.47 (m, 4H), 1.33–1.26 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.6, 145.7, 132.8, 127.2, 123.9, 119.6, 110.0, 52.1, 46.6, 42.8, 39.5, 26.3, 25.4, 24.3, 21.5; IR ν_{max} (neat) 2938, 2858, 1642 (C=O), 1550 cm^{-1}; EIMS *m/z* (%) 272 (12.8, M^+), 160 (47.8), 146 (39.2), 132 (100), 118 (72.9, Bt), 84 (100, piperidyl). Anal. Calcd for $C_{15}H_{20}N_4O$: C, 66.15; H, 7.40; N, 20.57. Found: C, 65.85; H, 7.49; N, 20.35.

*4.3.2. 3-(1H-Benzo[d][1,2,3]triazol-1-yl)-N-phenethylbutanamide (**3lh**)*

Oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, *J*=8.4 Hz, 1H, ArH), 7.64 (d, *J*=8.4 Hz, 1H, ArH), 7.48 (t, *J*=8.0 Hz, 1H, ArH), 7.35 (t, *J*=7.6 Hz, 1H, ArH), 7.22–7.14 (m, 3H, ArH), 6.97 (d, *J*=6.8 Hz, 2H, ArH), 6.31 (br s, 1H, CONH), 5.46–5.41 (m, 1H, H-3), 3.37–3.30 (m, 2H, CH_2), 3.08 (dd, *J*=8.4, 14.8 Hz, 1H, H-2a), 2.92 (dd, *J*=6.0, 14.8 Hz, 1H, H-2b), 2.56–2.47 (m, 2H, CH_2), 1.71 (d, *J*=6.8 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.4, 145.6, 138.6, 132.9, 128.6, 128.5, 127.4, 126.4, 124.2, 119.6, 110.0, 52.2, 43.4, 40.7, 35.4, 21.1; IR ν_{max} (neat) 3304 (NH), 3066, 3029, 2978, 2931, 1669 (C=O), 1549 cm^{-1}; EIMS *m/z* (%) 308 (65.8, M^+), 188 (100, $M^+-PhCH_2CH_2NH$), 118 (100, Bt). Anal. Calcd for $C_{18}H_{20}N_4O$: C, 70.11; H, 6.54; N, 18.17. Found: C, 69.06; H, 6.65; N, 18.20.

*4.3.3. 3-(1H-Benzo[d][1,2,3]triazol-1-yl)-N-butylbutanamide (**3nh**)*

Oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J*=8.4 Hz, 1H, ArH), 7.66 (d, *J*=8.4 Hz, 1H, ArH), 7.48 (t, *J*=7.2 Hz, 1H, ArH), 7.36 (t, *J*=7.6 Hz, 1H, ArH), 6.61 (br s, 1H, CONH), 5.49–5.45 (m, 1H, H-3), 3.20–2.98 (m, 4H, CH_2, H-2a, H-2b), 1.75 (d, *J*=6.8 Hz, 3H, Me), 1.21–1.16 (m, 2H, CH_2), 1.12–1.04 (m, 2H, CH_2), 0.74 (t, *J*=7.2 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.4, 145.5, 132.9, 127.3, 124.2, 119.4, 110.0, 52.4, 43.5, 39.2, 31.2, 21.1, 19.8, 13.6; IR ν_{max} (neat) 3307 (NH), 3073, 2960, 2932, 2873, 1666 (C=O), 1551 cm^{-1}; EIMS *m/z* (%) 261 (1.0, M^++1), 160 (26.2), 146 (11.3), 132 (80.0), 118 (100, Bt), 57 (65.3, *n*-Bu). Anal. Calcd for $C_{14}H_{20}N_4O$: C, 64.59; H, 7.74; N, 21.52. Found: C, 63.90; H, 7.86; N, 21.26.

*4.3.4. 3-(1H-Benzo[d][1,2,3]triazol-1-yl)-N,N-diethylbutanamide (**3qh**)*

Mp 78–80 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J*=8.4 Hz, 1H, ArH), 7.67 (d, *J*=8.4 Hz, 1H, ArH), 7.48 (t, *J*=7.6 Hz, 1H, ArH), 7.35 (t, *J*=8.0 Hz, 1H, ArH), 5.56–5.51 (m, 1H, H-3), 3.40–3.14 (m, 5H, 2×CH_2, H-2a), 2.95 (dd, *J*=5.6, 15.6 Hz, 1H, H-2b), 1.77 (d, *J*=6.8 Hz, 3H, Me), 1.12 (t, *J*=7.2 Hz, 3H, Me), 0.88 (t, *J*=7.2 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 145.6, 132.9, 127.1, 123.9, 119.6, 110.0, 52.1, 42.0, 40.3, 39.6, 21.3, 14.3, 12.7; IR ν_{max} (KBr) 2988, 2970, 2931, 1633 (C=O) cm^{-1}; EIMS *m/z* (%) 260 (5.7, M^+), 160 (89.8), 132 (100), 118 (96.1, Bt), 72 (100, Et_2N). Anal. Calcd for $C_{14}H_{20}N_4O$: C, 64.59; H, 7.74; N, 21.52. Found: C, 64.30; H, 7.85; N, 21.63.

4.4. General procedure for the aza-Michael addition of aromatic amines to α,β-unsaturated aliphatic *N*-acylbenzotriazoles (Table 3)

To a stirred solution of the appropriate α,β-unsaturated aliphatic *N*-acylbenzotriazole (1 mmol) and the corresponding aliphatic amine (1.1 mmol) in THF (10 mL) was added triethylamine (1 mL). The resulting mixture was stirred at room temperature for the indicated time (monitored by TLC) and then concentrated under reduced pressure to give a residue, which was then purified by flash column chromatography (cyclohexane–EtOAc) to afford the corresponding β-amino-*N*-acylbenzotriazole **5**.

*4.4.1. 3-(p-Toluidino)-1-(1H-benzo[d][1,2,3]triazol-1-yl)-butan-1-one (**5bh**)*

Mp 131–133 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (d, *J*=8.4 Hz, 1H, ArH), 8.09 (d, *J*=8.4 Hz, 1H, ArH), 7.61 (t, *J*=8.0 Hz, 1H, ArH), 7.47 (d, *J*=8.0 Hz, 1H, ArH), 6.94 (d, *J*=7.2 Hz, 2H, ArH), 6.59 (d, *J*=8.0 Hz, 2H, ArH), 4.32–4.27 (m, 1H, CH, H-3), 3.78 (dd, *J*=6.0, 15.2 Hz, 1H, H-2a), 3.42 (dd, *J*=6.4, 15.2 Hz, 1H, H-2b), 2.18 (s, 3H, Me), 1.39 (d, *J*=6.4 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.0, 145.4, 135.4, 134.0, 132.9, 129.4, 127.5, 124.4, 120.3, 119.4, 110.0, 52.2, 43.8, 20.9, 20.1; IR ν_{max} (KBr) 3303 (NH), 3266, 3193, 3121, 3064, 2937, 2919, 1688 (C=O), 1606 cm^{-1}; EIMS *m/z* (%) 294 (70.2, M^+), 188 (100, $M^+-p\text{-}CH_3C_6H_4NH$), 160 (100), 132 (100), 118 (78.2, Bt), 106 (100), 91 (100); ESI-HRMS calcd for $C_{17}H_{19}N_4O$ $[M+H]^+$ 295.1559, found 295.1557.

*4.4.2. 1-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-(4-methoxyphenylamino)butan-1-one (**5eh**)*

Oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (d, *J*=8.4 Hz, 1H, ArH), 8.11 (d, *J*=8.4 Hz, 1H, ArH), 7.65 (t, *J*=7.2 Hz, 1H, ArH), 7.51 (t, *J*=8.0 Hz, 1H, ArH), 6.75–6.71 (m, 2H, ArH), 6.67–6.64 (m, 2H, ArH), 4.26–4.24 (m, 1H, H-3), 3.80 (dd, *J*=6.4, 15.2 Hz, 1H, H-2a), 3.70 (s, 3H, Me), 3.42 (dd, *J*=6.8, 15.2 Hz, 1H, H-2b), 1.40 (d, *J*=6.4 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.0, 146.2, 140.5, 131.0, 130.5, 126.3, 125.8, 120.1, 115.8, 115.0, 114.5, 55.7, 47.9, 42,3, 21.1; IR ν_{max} (KBr) 3236 (NH), 3178, 3065, 2830, 1691 (C=O), 1603 cm^{-1}; ESI-HRMS calcd for $C_{17}H_{19}N_4O$ $[M+H]^+$ 311.1508, found 311.1562.

*4.4.3. 3-(p-Toluidino)-1-(1H-benzo[d][1,2,3]triazol-1-yl)-2-methylpropan-1-one (**5bi**)*

Mp 100–102 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (d, *J*=8.0 Hz, 1H, ArH), 8.11 (d, *J*=8.0 Hz, 1H, ArH), 7.65 (t, *J*=8.0 Hz, 1H, ArH), 7.50 (t, *J*=8.0 Hz, 1H, ArH), 6.94 (d, *J*=8.0 Hz, 2H, ArH), 6.55 (d, *J*=8.4 Hz, 2H, ArH), 4.48–4.43 (m, 1H, CH, H-3), 3.88 (br s, 1H, NH), 3.77 (dd, *J*=8.0, 16.0 Hz, 1H, CH, H-2a), 3.44 (dd, *J*=8.0, 16.0 Hz, 1H, CH, H-2b), 2.19 (s, 3H, Me), 1.49 (d, *J*=8.0, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 146.2, 145.1, 131.2, 130.4, 129.8, 127.2, 126.2, 120.2, 114.6, 113.2, 47.5, 39.6, 20.3, 15.4; IR ν_{max} (KBr) 3398 (NH), 3134, 1729 (C=O), 1619 cm^{-1}; ESI-HRMS calcd for $C_{17}H_{19}N_4O$ $[M+H]^+$ 295.1559, found 295.1545.

*4.4.4. 1-(1H-Benzo[d][1,2,3]triazol-1-yl)-3-(4-chlorophenylamino)-2-methylpropan-1-one (**5gi**)*

Mp 105–107 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (d, *J*=8.4 Hz, 1H, ArH), 8.12 (d, *J*=8.4 Hz, 1H, ArH), 7.67 (t, *J*=7.6 Hz, 1H, ArH), 7.52

(t, J=8.0 Hz, 1H, ArH), 7.07 (d, J=8.8 Hz, 2H, ArH), 6.55 (d, J=8.4 Hz, 2H, ArH), 4.48–4.42 (m, 1H, H-3), 4.05 (br s, 1H, NH), 3.80–3.73 (m, 1H, H-2a), 3.47–3.41 (m, 1H, H-2b), 1.49 (d, J=7.2 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.8, 146.2, 145.9, 131.1, 130.6, 129.1, 126.4, 122.5, 120.2, 114.5, 114.0, 47.1, 39.5, 15.4; IR ν_{max} (KBr) 3393 (NH), 3128, 1728 (C=O), 1601 cm^{-1}; ESI-HRMS calcd for $C_{16}H_{16}ClN_4O$ $[M+H]^+$ 315.1013, found 315.1007.

4.4.5. *3-(m-Toluidino)-1-(1H-benzo[d][1,2,3]triazol-1-yl)-2-methylpropan-1-one (**5ci**)*

Mp 78–80 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (d, J=8.4 Hz, 1H, ArH), 8.11 (d, J=8.0 Hz, 1H, ArH), 7.64 (t, J=8.0 Hz, 1H, ArH), 7.50 (t, J=8.0 Hz, 1H, ArH), 7.05–7.01 (m, 1H, ArH), 6.50–6.44 (m, 3H, ArH), 4.48–4.43 (m, 1H, H-3), 3.99 (br s, 1H, NH), 3.78 (dd, J=8.0, 16.0 Hz, 1H, H-2a), 3.46 (dd, J=4.0, 12.0 Hz, 1H, H-2b), 2.23 (s, 3H, Me), 1.50 (d, J=4.0 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 147.4, 146.2, 139.1, 131.2, 130.5, 129.2, 126.3, 120.2, 118.8, 114.6, 113.7, 110.1, 47.1, 39.6, 21.6, 15.4; IR ν_{max} (KBr) 3388 (NH), 3116, 3036, 2979, 1732 (C=O), 1605 cm^{-1}; ESI-HRMS calcd for $C_{17}H_{19}N_4O$ $[M+H]^+$ 295.1559, found 295.1563.

4.5. Typical procedure for the acylation of *p*-anisidine with β-amino-*N*-acylbenzotriazole 5ci

To 10 mL of dry THF were added $ZnCl_2$ (0.014 g, 0.1 mmol), *p*-anisidine (0.068 g, 0.55 mmol), and β-amino-*N*-acylbenzotriazole **5ci** (0.147 g, 0.5 mmol). The mixture was stirred at room temperature for 1 h and dilute hydrochloric acid (0.3 N, 5 mL) was added. The resulting mixture was extracted with ethyl acetate (10 mL×3), and the combined organic layer was washed by saturated Na_2CO_3 and then by brine. Removal of the solvent and purification by flash column chromatography (cyclohexane–EtOAc 4:1) afforded 0.122 g of compound **6** (82% yield).

4.5.1. *3-(m-Toluidino)-N-(4-methoxyphenyl)-2-methylpropanamide (**6**)*

Mp 117–119 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (br s, 1H, CONH), 7.35 (d, J=8.8 Hz, 2H, ArH), 7.08 (t, J=8.0 Hz, 1H, ArH), 6.82 (d, J=8.8 Hz, 2H, ArH), 6.57 (d, J=7.6 Hz, 1H, ArH), 6.45–6.46 (m, 2H, ArH), 3.77 (s, 3H, Me), 3.41 (dd, J=9.2, 10.2 Hz, 1H, H-3a), 3.46 (dd, J=4.4, 9.9 Hz, 1H, H-3b), 2.74–2.69 (m, 1H, H-2), 2.28 (s, 3H, Me), 1.28 (d, J=6.8 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.2, 156.4, 147.5, 139.3, 130.9, 129.3, 121.8, 119.1, 114.2, 114.1, 110.5, 55.5, 47.7, 41.1, 21.6, 15.5; IR ν_{max} (KBr) 3375 (NH), 3128 (NH), 1644 (C=O), 1607, 1607, 1400 cm^{-1}. Anal. Calcd for $C_{18}H_{22}N_2O_2$: C, 72.46; H, 7.43; N, 9.39. Found: C, 72.56; H, 7.48; N, 9.36.

4.6. General procedure for the acylation of aliphatic amines with *N*-cinnamoylbenzotriazoles (Table 4)

To a stirred solution of the appropriate *N*-cinnamoylbenzotriazole (1 mmol) and the corresponding aliphatic amine (1.1 mmol) in THF (10 mL) was added triethylamine (1 mL). The resulting mixture was refluxed for the indicated time (monitored by TLC), then diluted with Et_2O (60 mL), and washed with saturated aqueous $NaHCO_3$. The organic layer was dried over $MgSO_4$ and concentrated in vacuo to give a residue, which was either recrystallized from EtOH or purified by flash column chromatography (cyclohexane–EtOAc) to afford the corresponding α,β-unsaturated amide **4**.

4.6.1. *(E)-N-Cyclohexyl-3-p-tolylacrylamide (**4kd**)*

Mp 165–167 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, J=15.6 Hz, 1H, C=CH), 7.39 (d, J=8.0 Hz, 2H, ArH), 7.16 (d, J=8.0 Hz, 2H, ArH), 6.31 (d, J=15.6 Hz, 1H, C=CH), 5.44 (br, d, J=6.4 Hz, 1H, CONH), 3.92–3.90 (m, 1H, CH), 2.36 (s, 3H, Me), 2.00–1.97 (m, 2H, Cy), 1.75–1.72 (m, 2H, Cy), 1.43–1.36 (m, 2H, Cy), 1.25–1.14 (m, 4H, Cy); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.1, 140.6, 139.8, 132.2, 129.5, 127.7, 120.1, 48.3, 33.3, 25.6, 24.9, 21.4; IR ν_{max} (KBr) 3288 (NH), 3072, 3025, 2927, 2853, 1660 (C=O), 1618, 1553 cm^{-1}; EIMS *m*/*z* (%) 244 (26.2, M^++1), 243 (75.5, M^+), 160 (100, M^+−Cy); ESI-HRMS calcd for $C_{16}H_{22}NO$ $[M+H]^+$ 244.1701, found 244.1690.

4.6.2. *(E)-3-(4-Chlorophenyl)-N-phenethylacrylamide (**4lf**)*

Mp 174–176 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, J=15.6 Hz, 1H, C=CH), 7.40 (m, 3H, ArH), 7.35–7.22 (m, 6H, ArH), 6.28 (d, J=15.6 Hz, 1H, C=CH), 5.60 (br s, 1H, CONH), 3.67 (q, J=6.8 Hz, 2H), 2.89 (t, J=6.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.6, 139.7, 138.8, 135.5, 133.3, 129.1, 128.9, 128.7, 128.6, 126.6, 121.2, 40.8, 35.6; IR ν_{max} (KBr) 3309 (NH), 3085, 3032, 2925, 2853, 1655 (C=O), 1623, 1550 cm^{-1}; ESI-HRMS calcd for $C_{17}H_{17}ClNO$ $[M+H]^+$ 286.0999, found 286.0989.

4.6.3. *(E)-3-(4-Methoxyphenyl)-N-propylacrylamide (**4mg**)*

Mp 104–106 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, J=15.6 Hz, 1H, C=CH), 7.42 (d, J=8.0 Hz, 2H, ArH), 6.87–6.84 (m, 2H, ArH), 6.34–6.29 (m, 1H, C=CH), 6.02 (br s, 1H, CONH), 3.80 (s, 3H, Me), 3.34 (q, J=6.8 Hz, 2H), 1.62–1.56 (m, 2H), 0.95 (t, J=7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 160.8, 140.2, 129.3, 127.7, 118.6, 114.2, 55.3, 41.5, 23.0, 11.4; IR ν_{max} (KBr) 3268 (NH), 3072, 2966, 2934, 2871, 1657 (C=O), 1605, 1554 cm^{-1}; ESI-HRMS calcd for $C_{13}H_{18}NO_2$ $[M+H]^+$ 220.1338, found 220.1327.

4.6.4. *(E)-N-Butyl-3-(4-chlorophenyl)acrylamide (**4nf**)*

Mp 115–117 °C (lit.[26] 115–116 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (d, J=15.6 Hz, 1H, C=CH), 7.41 (d, J=8.0 Hz, 2H, ArH), 7.32 (d, J=8.0 Hz, 2H, ArH), 6.37 (d, J=15.6 Hz, 1H, C=CH), 5.99 (br s, 1H, CONH), 3.39 (q, J=6.8 Hz, 2H), 1.59–1.52 (m, 2H), 1.44–1.36 (m, 2H), 0.94 (t, J=7.2 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.7, 139.4, 135.4, 133.4, 129.0, 128.9, 121.5, 39.6, 31.7, 20.1, 13.8; IR ν_{max} (KBr) 3297 (NH), 3068, 2960, 2933, 2871, 1653 (C=O), 1618, 1547 cm^{-1}.

4.6.5. *(E)-3-(4-Nitrophenyl)-N-propylacrylamide (**4me**)*

Mp 124–126 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (d, J=8.8 Hz, 2H, ArH), 7.69–7.63 (m, 3H), 6.54 (d, J=15.6 Hz, 1H, C=CH), 5.85 (br s, 1H, CONH), 3.38 (q, J=6.8 Hz, 2H), 1.64–1.59 (m, 2H), 0.98 (t, J=7.6 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 148.2, 141.2, 138.2, 128.2, 125.0, 124.0, 41.6, 22.7, 11.4; IR ν_{max} (KBr) 3255 (NH), 3075, 2963, 2923, 2880, 1658 (C=O), 1623, 1555 cm^{-1}; ESI-HRMS calcd for $C_{12}H_{15}N_2O_3$ $[M+H]^+$ 235.1083, found 235.1071.

4.6.6. *(E)-3-Phenyl-1-(piperidin-1-yl)prop-2-en-1-one (**4oa**)*

Mp 116–118 °C (lit.[27] 114–117 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, J=15.6 Hz, 1H, C=CH), 7.52 (d, J=7.6 Hz, 2H, ArH), 7.38–7.27 (m, 3H, ArH), 6.90 (d, J=15.6 Hz, 1H, C=CH), 3.66–3.59 (m, 4H), 1.69–1.61 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.4, 142.1, 135.5, 129.4, 128.8, 127.7, 117.8, 47.0, 43.4, 26.8, 25.6, 24.7; IR ν_{max} (KBr) 3027, 2935, 2856, 1645 (C=O), 1589 cm^{-1}; ESI-HRMS calcd for $C_{14}H_{18}NO$ $[M+H]^+$ 216.1388, found 216.1381.

4.6.7. *(E)-1-Morpholino-3-phenylprop-2-en-1-one (**4pa**)*

Mp 64–66 °C (lit.[28] 65 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, J=15.6 Hz, 1H, C=CH), 7.55–7.52 (m, 2H, ArH), 7.40–7.37 (m, 3H, ArH), 6.86 (d, J=15.6 Hz, 1H, C=CH), 3.74–3.70 (m, 8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.6, 143.2, 135.1, 129.8, 128.8, 127.8, 116.6, 66.9; IR ν_{max} (KBr) 2965, 2923, 2857, 1650 (C=O), 1599 cm^{-1}.

4.6.8. *(E)-3-(4-Chlorophenyl)-N,N-diethylacrylamide (**4qf**)*

Oil;[29] ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, J=15.6 Hz, 1H, C=CH), 7.46 (d, J=8.4 Hz, 2H, ArH), 7.33 (d, J=8.4 Hz, 2H, ArH), 6.80 (d, J=15.6 Hz, 1H, C=CH), 3.50–3.44 (m, 4H), 1.27–1.17 (m, 6H); ^{13}C

NMR (100 MHz, $CDCl_3$) δ 165.4, 140.8, 135.2, 134.0, 129.0, 128.9, 118.4, 42.3, 41.1, 15.1, 13.2; IR ν_{max} (KBr) 3075, 2990, 1660 (C=O), 1615, 1580 cm^{-1}.

4.6.9. *(E)-N,N-Diethyl-3-(furan-2-yl)acrylamide (**4qc**)*[30]

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49–7.44 (m, 2H), 6.74 (d, J=15.2 Hz, 1H, C=CH), 6.52–6.44 (m, 2H, ArH), 3.47–3.45 (m, 4H), 1.25–1.16 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.5, 151.7, 143.7, 129.1, 115.2, 113.5, 112.1, 42.2, 41.0, 15.0, 13.1; IR ν_{max} (neat): 3117 (NH), 2975, 2931, 1651, 1605 cm^{-1}.

4.7. General procedure for the synthesis of heterocycles 7 and 8 (Tables 5 and 6)

To a stirred solution of the appropriate α,β-unsaturated *N*-acylbenzotriazole (1 mmol) and *o*-phenylenediamine or *o*-aminothiophenol (1.1 mmol) in THF (10 mL) was added triethylamine (1 mL). The resulting mixture was refluxed until the disappearance of the α,β-unsaturated *N*-acylbenzotriazole, as determined by TLC, and then concentrated under reduced pressure to give a residue, which was then purified by flash column chromatography (cyclohexane–EtOAc) to afford the corresponding 1,5-benzodiazepine-2-one **7** or 2,3-dihydrobenzo[*b*][1,4]thiazepin-4(5*H*)-one **8**.

4.7.1. *4-Phenyl-4,5-dihydro-1H-benzo[b][1,4]diazepin-2(3H)-one (**7ra**)*

Mp decomposed beyond 83 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (s, 1H, CONH), 7.45–7.30 (m, 5H, ArH), 7.09–7.07 (m, 1H, ArH), 6.96–6.94 (m, 2H, ArH), 6.85 (d, J=8.0 Hz, 1H, ArH), 5.04 (dd, J=4.0, 12.0 Hz, 1H, H-4), 3.85 (br s, 1H, NH), 2.91 (dd, J=8.0, 12.0 Hz, 1H, H-3a), 2.78 (dd, J=4.0, 12.0 Hz, 1H, H-3b); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.8, 144.2, 138.5, 129.0, 128.2, 127.7, 126.3, 126.1, 122.6, 121.6, 121.2, 63.5, 41.8; IR ν_{max} (KBr) 3335 (NH), 3178, 3060, 2958, 2904, 1666 (C=O), 1596 cm^{-1}; EIMS m/z (%) 239 (22.1, M$^+$+1), 238 (100, M$^+$); ESI-HRMS calcd for $C_{15}H_{15}N_2O$ $[M+H]^+$ 239.1184, found 239.1184.

4.7.2. *4-(Furan-2-yl)-4,5-dihydro-1H-benzo[b][1,4]diazepin-2(3H)-one (**7rc**)*

Mp 180–182 °C (lit.[31] 185 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (br s, 1H, CONH), 7.51–7.30 (m, 2H, ArH), 7.06–6.95 (m, 2H, ArH), 6.81 (d, J=7.6 Hz, 1H, ArH), 6.59–6.47 (m, 1H, ArH), 6.32–6.23 (m, 1H, ArH), 5.08 (dd, J=4.4, 9.6 Hz, 1H, H-4), 3.88 (br s, 1H, NH), 2.93 (dd, J=9.6, 13.6 Hz, 1H, H-3a), 2.80 (dd, J=4.4, 9.2 Hz, 1H, H-3b); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.0, 155.5, 142.2, 137.6, 129.2, 126.1, 122.5, 122.2, 122.1, 110.3, 105.6, 57.0, 38.1; IR ν_{max} (KBr) 3323 (NH), 3188, 3057, 2946, 1660 (C=O) cm^{-1}.

4.7.3. *4-p-Tolyl-4,5-dihydro-1H-benzo[b][1,4]diazepin-2(3H)-one (**7rd**)*

Mp decomposed beyond 151 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (br s, 1H, CONH), 7.44 (s, 1H, ArH), 7.29–7.24 (m, 1H, ArH), 7.16 (d, J=8.0 Hz, 2H, ArH), 7.08–7.04 (m, 1H, ArH), 6.94–6.93 (m, 2H, ArH), 6.82 (d, J=8.0 Hz, 1H, ArH), 4.99(dd, J=4.0, 10.0 Hz, 1H, H-4), 3.80 (br s, 1H, NH), 2.87 (dd, J=9.6, 13.6 Hz, 1H, H-3a), 2.73 (dd, J=4.0, 13.2 Hz, 1H, H-3b), 2.34 (s, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.2, 141.4, 138.4, 137.9, 129.6, 127.7, 126.1, 125.9, 122.5, 121.5, 121.1, 63.0, 41.9, 21.1; IR ν_{max} (KBr) 3345 (NH), 3178, 3061, 2958, 1667 (C=O), 1602 cm^{-1}; ESI-HRMS calcd for $C_{16}H_{17}N_2O$ $[M+H]^+$ 253.1341, found 253.1331.

4.7.4. *4-(4-Chlorophenyl)-4,5-dihydro-1H-benzo[b][1,4]diazepin-2(3H)-one (**7rf**)*

Mp decomposed beyond 145 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (br s, 1H, CONH), 7.47–7.44 (m, 2H, ArH), 7.35–7.30 (m, 3H, ArH), 7.09–7.07 (m, 1H, ArH), 6.98–6.96 (m, 1H, ArH), 6.85 (d, J=7.6 Hz, 1H, ArH), 5.05 (t, J=6.4 Hz, 1H, H-4), 3.79 (br s, 1H, NH), 2.82 (d, J=6.8 Hz, 2H, H-3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.9, 142.5, 138.2, 133.9, 129.1, 128.0, 127.4, 126.3, 122.5, 121.9, 121.3, 62.9, 41.5; IR ν_{max} (KBr) 3291 (NH), 3220, 3045, 2959, 1670 (C=O), 1596 cm^{-1}; ESI-HRMS calcd for $C_{15}H_{14}ClN_2O$ $[M+H]^+$ 273.0795, found 273.0798.

4.7.5. *4-(4-Nitrophenyl)-4,5-dihydro-1H-benzo[b][1,4]diazepin-2(3H)-one (**7re**)*

Mp decomposed beyond 185 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, J=8.8 Hz, 2H, ArH), 8.14 (br s, 1H, CONH), 7.62 (d, J=8.0 Hz, 2H, ArH), 7.13–7.09 (m, 1H, ArH), 7.00–6.89 (m, 3H, ArH), 5.20 (m, 1H, H-4), 3.88 (s, 1H, NH), 2.91 (dd, J=4.0, 12.0 Hz, 1H, H-3a), 2.75 (dd, J=8.0, 12.0 Hz, 1H, H-3b); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.1, 150.8, 147.7, 138.0, 128.4, 127.1, 126.4, 124.2, 122.6, 122.4, 121.4, 63.0 41.0; IR ν_{max} (KBr) 3304 (NH), 3227, 3075, 2980, 1671 (C=O), 1601 cm^{-1}; ESI-HRMS calcd for $C_{15}H_{14}N_3O_3$ $[M+H]^+$ 284.1035, found 284.1037.

4.7.6. *4-Methyl-4,5-dihydro-1H-benzo[b][1,4]diazepin-2(3H)-one (**7rh**)*

Mp 182–184 °C (lit.[29] 184 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (br s, 1H, CONH), 7.03–6.98 (m, 1H, ArH), 6.91–6.87 (m, 2H, ArH), 6.79–6.77 (m, 1H, ArH), 4.06–4.00 (m, 1H, H-4), 3.53 (br s, 1H, NH), 2.93 (dd, J=4.0, 13.6 Hz, 1H, H-3a), 2.47–2.41 (m, 1H, H-3b), 1.33 (d, J=6.4 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.3, 138.3, 128.0, 125.6, 122.2, 121.3, 120.9, 54.1, 41.5, 23.7; IR ν_{max} (KBr) 3300 (NH), 3181, 3034, 2966, 1658 (C=O), 1595 cm^{-1}.

4.7.7. *2-(4-Nitrophenyl)-2,3-dihydrobenzo[b][1,4]thiazepin-4(5H)-one (**8se**)*

Mp 187–189 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30 (br s, 1H, CONH), 8.16 (d, J=8.8 Hz, 2H, ArH), 7.37 (d, J=8.8 Hz, 2H, ArH), 7.31–7.19 (m, 2H, ArH), 7.08–7.04 (m, 1H, ArH), 6.87–6.85 (m, 1H, ArH), 3.68 (dd, J=5.6, 9.6 Hz, 1H, H-2), 3.41 (dd, J=5.6, 14.0 Hz, 1H, H-3a), 2.98 (dd, J=9.2, 14.0 Hz, 1H, H-3b); ^{13}C NMR (400 MHz, $CDCl_3$) δ 166.9, 147.1, 144.6, 135.8, 130.3, 128.4, 127.6, 124.4, 123.7, 118.1, 117.1, 43.6, 35.3; IR ν_{max} (KBr) 3122, 3115, 2894, 1663 (C=O), 1605 cm^{-1}; EIMS m/z (%) 300 (45.0, M$^+$), 164 (100), 134 (75.0). Anal. Calcd for $C_{15}H_{12}N_2O_3S$: C, 59.99; H, 4.03; N, 9.33. Found: C, 58.96; H, 4.11; N, 9.26.

4.7.8. *2-(4-Chlorophenyl)-2,3-dihydrobenzo[b][1,4]thiazepin-4(5H)-one (**8sf**)*

Mp 205–207 °C (lit.[32] 207–208 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (br s, 1H, CONH), 7.65 (d, J=8.8 Hz, 1H, ArH), 7.46–7.42 (m, 1H, ArH), 7.30–7.24 (m, 5H, ArH), 7.17 (d, J=8.0 Hz, 1H, ArH), 4.85 (dd, J=6.0, 10.4 Hz, 1H, H-2), 2.88–2.77 (m, 2H, H-3); ^{13}C NMR (400 MHz, $CDCl_3$) δ 172.0, 141.7, 141.3, 135.8, 133.6, 130.4, 129.0, 127.9, 126.8, 126.3, 123.3, 52.5, 41.3; IR ν_{max} (KBr) 3184, 3106, 2894, 1661 (C=O) cm^{-1}; EIMS m/z (%) 291 (18.0, M$^+$, ^{37}Cl), 289 (49.0, M$^+$, ^{35}Cl), 165 (100), 125 (100).

4.7.9. *2-Methyl-2,3-dihydrobenzo[b][1,4]thiazepin-4(5H)-one (**8sh**)*[33]

Mp 201–203 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (br s, 1H, CONH), 7.60 (d, J=7.6 Hz, 1H, ArH), 7.36 (t, J=7.6 Hz, 1H, ArH), 7.17 (t, J=7.6 Hz, 1H, ArH), 7.10 (d, J=7.6 Hz, 1H, ArH), 3.94–3.86 (m, 1H, H-2), 2.65 (dd, J=5.6, 12.4 Hz, 1H, H-3a), 2.34 (dd, J=8.8, 12.4 Hz, 1H, H-3b), 1.43 (d, J=6.4 Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.8, 141.4, 135.9, 129.9, 126.7, 126.3, 123.1, 44.9, 41.3, 23.6; IR ν_{max} (KBr) 3178, 3111, 2954, 1682 (C=O) cm^{-1}.

4.7.10. *3-Methyl-2,3-dihydrobenzo[b][1,4]thiazepin-4(5H)-one (**8si**)*

Mp 176–178 °C (lit.[34] 177.5–178.5 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (br s, 1H, CONH), 7.58 (d, J=7.6 Hz, 1H, ArH), 7.35 (t, J=7.6 Hz, 1H, ArH), 7.17–7.13 (m, 2H, ArH), 3.48 (dd, $J=5.6$, 10.8 Hz, 1H, H-2), 3.00 (t, $J=12.0$ Hz, 1H, H-3a), 2.81–2.75 (m, 1H, H-3b), 1.18 (d, $J=6.8$ Hz, 3H, Me); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.1, 141.3, 135.1, 129.7, 127.6, 126.3, 123.5, 41.6, 36.6, 15.5; IR $\nu_{\max}$ (KBr) 3187, 3113, 3066, 2964, 2895, 1677 (C=O) cm^{-1}; ESI-HRMS calcd for $C_{10}H_{12}NOS$ $[M+H]^+$ 194.0640, found 194.0643.

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Supplementary data

Copies of ^{1}H and ^{13}C NMR spectra for new compounds **2**, compounds **3**, **4**, **5**, **7** and **8**. Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.tet.2008.04.054.

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