Visible-light-promoted N–H functionalization of O-substituted hydroxamic acid with diazo esters†

Shuangshuang Xia, Yongchan Jian, Liwen Zhang, Cheng Zhang, Yuanyuan An † and Yubin Wang †

Herein we report an N–H functionalization of O-substituted hydroxamic acid with diazo esters under blue LED irradiation conditions. The present transformations could be performed efficiently under mild conditions without use of catalyst, additive and N₂ atmosphere. Interestingly, when THF and 1,4-dioxane were employed as the reaction solvents, an active oxonium ylide involved three-component reaction and an N–H insertion of carbene species into hydroxamate occurred, respectively.

From recent decades, diazo compounds have been widely employed as an efficient reagent in numerous organic transformations.¹ For instance, they could be applied for constructing cyclopropane skeletons by transferring a carbene unit to a double bond with specific diastereoselectivity.² Moreover, diazo compounds could also be involved in transition metal catalysed carbene transfer reactions, which resulted in the development of various strategies for the construction of new C–C and C–X (X = N, O, S, Se, Si, Sn, Ge) bonds.³

Recently, visible light mediated transformations of donor/acceptor diazo compounds have been intensively studied.⁴ Until now, under visible light irradiation conditions, the conversion of donor/acceptor diazo compounds is mainly applied for cyclopropanation,⁵ insertion reaction of X–H (X = B, C, O, N, Si, S) bond⁶ via the formation of free carbene as a key intermediate, and some conversion that involves the formation of ylide intermediates.⁷,⁸ In 2018, Davies and Jurberg first revealed that aryl diazoacetates had absorption in the visible light region (λ = 400–500 nm).⁹ They found that aryl diazoacetates could occur cyclopropanation with styrene,¹⁰ O–H insertion reactions with oxime,¹¹ N–H insertion reactions with amines and C–H insertion reactions with cyclic alkanes or arenes (Scheme 1a).¹² Subsequently, Guo and Qiu reported a visible light promoted S–H insertion reaction of aryl diazoacetates and cysteine residues in batch and flow (Scheme 1b).¹³ Afterwards, photochemical multicomponent reactions involving aryl diazoacetates have been developed successively.¹⁴

As our research interests on the development of photochemical insertion reactions of X–H-containing molecules into aryl diazoacetates, herein we report a visible-light-promoted N–H functionalization of O-substituted hydroxamates with aryl diazoacetates. It was found that when THF was the reaction solvent, a three-component coupling product was obtained, while when 1,4-dioxane was used as the solvent, an N–H insertion product was achieved (Scheme 1c). As a multicomponent reaction between hydroxamic acid and diazo esters has been developed,¹⁵ this work will be a good supplement to the photochemical transformation of diazo compounds through the formation of free carbene as a key intermediate.

At the outset, we evaluated the reaction using methyl 2-diazo-2-phenylacetate 1a and N-(benzyloxy)-2-bromo-2-methylpropanamide 2a as the model substrates. Initially, under the irradiation of 30 W blue LEDs, the reaction was conducted in THF in the presence of NaHCO₃ (Table 1, entry 1), but only trace amount of product 3aa was observed. Next, some stronger bases were employed in the reaction system. To our

Scheme 1 Visible light induced carbene insertion reaction of diazo compounds.
delight, the THF incorporated product methyl (R)-2-(4-(N-(benzyloxy)methacrylamido)butoxy)-2-phenylacetate 3aa could be isolated in good yields (Table 1, entries 2–4). Especially, when KOtBu was taken as the base, product 3aa could be isolated in 90% yield (Table 1, entry 4). Characterization of product 3aa by 1H NMR, 13C NMR and HRMS indicated that an intramolecular elimination of one molecular HBr occurred. Furthermore, control experiment under dark conditions was conducted, the result of which demonstrated the necessity of visible light irradiation condition (Table 1, entry 5). The impact of water on this transformation was studied, when 1.0 equiv. of water was added into the reaction system, except for product 3aa (28% yield), an N–H insertion product methyl (R)-2-(N-(benzyloxy)methacrylamido)-2-phenylacetate 4aa was produced in 60% yield when 1,4-dioxane was employed as the solvent (Table 1, entry 6). Further exploration of different kinds of bases including Cs2CO3, NaOH and NaHCO3 didn’t bring better results (Table 1, entries 7–9). Inferior results were observed when the reaction solvent was changed to DCE, DMF or CH3CN (Table 1, entries 10–12). Control experiment was also performed, the result showed that visible light irradiation was necessary for the generation of product 4aa (Table 1, entry 13).

Interestingly enough, N–H insertion product methyl (R)-2-(N-(benzyloxy)methacrylamido)-2-phenylacetate 4aa was produced in 60% yield when 1,4-dioxane was employed as the solvent (Table 1, entry 6). Further exploration of different kinds of bases including Cs2CO3, NaOH and NaHCO3 didn’t bring better results (Table 1, entries 7–9). Inferior results were observed when the reaction solvent was changed to DCE, DMF or CH3CN (Table 1, entries 10–12). Control experiment was also performed, the result showed that visible light irradiation was necessary for the generation of product 4aa (Table 1, entry 13).

With the optimal reaction conditions in hand, we started to explore the substrate scope of the solvent-controlled N–H functionalization reaction of hydroxamates 2 with aryldiazocacetates 1. The results are shown in Schemes 2 and 3. Scheme 2

Presented the three-component reaction of aryldiazocacetates 1, hydroxamates 2 and THF. Methyl 2-diazo-2-phenylacetate with both electron-donating and electron-withdrawing groups like Me, CF3, F, Cl, Br at the ortho-, meta-, para-position of the benzene ring were all tolerated, resulting in the formation of products 3aa–3ia in good to excellent yields. For instance, the three-component reaction of methyl 2-(4-chlorophenyl)-2-diazoacetate, N-(benzyloxy)-2-bromo-2-methylpropionamide 2a

<table>
<thead>
<tr>
<th>Entry</th>
<th>Base</th>
<th>Solvent</th>
<th>Yield (%)</th>
<th>3aa</th>
<th>4aa</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>NaHCO3</td>
<td>THF</td>
<td>Trace</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>NaOH</td>
<td>THF</td>
<td>63</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>DBU</td>
<td>THF</td>
<td>50</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>KOtBu</td>
<td>THF</td>
<td>90</td>
<td>Trace</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>KOtBu</td>
<td>1,4-Dioxane</td>
<td>n.d.</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>KOtBu</td>
<td>Cs2CO3, 1,4-Dioxane</td>
<td>n.d.</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>NaOH</td>
<td>1,4-Dioxane</td>
<td>n.d.</td>
<td>43</td>
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</tr>
<tr>
<td>8</td>
<td>NaHCO3</td>
<td>1,4-Dioxane</td>
<td>n.d.</td>
<td>Trace</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>KOtBu</td>
<td>DCE</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>KOtBu</td>
<td>DMF</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>KOtBu</td>
<td>CH3CN</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>KOtBu</td>
<td>1,4-Dioxane</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
</tr>
</tbody>
</table>

* Reaction conditions: 1a (0.2 mmol), 2a (1.5 equiv.), base (1.2 equiv.), solvent (2 mL), 14 h, room temperature, 30 W blue LEDs (λ = 440–450 nm). † Isolated yields. ‡ Without light irradiation. n.d. = no desired product was detected.
and THF gave rise to the product 3ea in 87% yield. Additionally, the naphthyl-containing substrate 1j was also compatible with this protocol, generating the corresponding product 3ja in 79% yield. Subsequently, substituent modification of the ester group in aryl diazoacetates was investigated. The results showed that the replacement of methyl group with ethyl, n-hexyl, isopropyl, benzyl, cycloalkyl and other sensitive functional groups (1q and 1r) was feasible, leading to the corresponding products 3ka–3ra in good yields (51–91%). Unfortunately, the α-aryl diazo substrate 1s was failed to react with 2a and THF.

Then, we investigated the substrate scope of amide 2. The fluoro-group containing 2b was found to react with 1a or 1n smoothly, giving the corresponding products 3ab and 3nb in good yields. However, changing the OBn group to Bn group, no desired product 3ac was detected. To our delight, the tert-butyl substituted amide 2d worked well to produce product 3ad in 58% yield. Unfortunately, when N-(benzyl oxy)isobutyramide 2e or N-(benzyl oxy)-2-bromopropanamide 2f were taken as the substrate, both of the reaction were failed, no desired products (3ae, 3af) was observed. Additionally, aromatic amides bearing either electron-withdrawing or electron-donating groups were also tolerated, resulting in the formation of the corresponding products 3ag–3am in good yields. Moreover, using tetrahydrofuran as the reaction solvent, the corresponding product 5 was isolated in 51% yield. But, when 2-methyltetrahydrofuran or tetrahydrothiophene were taken as the reaction solvent, reactions were failed.

We further expanded the reaction scope of aryl diazoacetates 1 and hydroxamates 2 in 1,4-dioxane (Scheme 3). It was found that the incorporation of both electron-donating and electron-withdrawing groups on the phenyl ring of aryl diazoacetates generally afforded the corresponding N–H insertion product in 44–60% yields (Scheme 3, 4aa–4ga). In addition, the reaction of methyl 2-diazo-2-(naphthalen-2-yl)acetate 1h and N-(benzyl oxy)-2-bromo-2-methylpropanamide 2a also proceeded very well under the standard conditions, giving rise to 4ha in 47% yield. Moreover, a series of aryl diazoacetates were also demonstrated to react with 2a smoothly, leading to the formation of products 4la–4ma. As expected, various amides 2 reacted with methyl 2-diazo-2-phenylacetate 1a successfully, giving rise to the corresponding products 4ab–4ah in moderate yields. Different functional groups including F, Cl, Br, CF₃, Me, tBu were all tolerated under the reaction conditions.

As is shown in Scheme 4, a key intermediate 8 which was generated from an intramolecular elimination reaction of substrate 2a was detected in the reaction mixture (both in THF and 1,4-dioxane) by HRMS. Additionally, in the THF reaction system, the ylide intermediate 9 was also detected by HRMS (Scheme 4a). When we performed the reaction of 1a and 2a in the absence of base (Scheme 4c), it was found that the N–H insertion reaction still worked but without in situ dehydrobromination occurring, product 10 could be obtained in 68% yield, while in this reaction system product 3aa could not be detected. Then, we prepared N-(benzyl oxy)methacrylamide 8 as the substrate, and under the irradiation with 30 W blue LEDs we conducted the reaction of 8 with 1a in THF which resulted in the formation of product 3aa in 68% yield (Scheme 4d).

Based on the results of control experiments and previous reports, a plausible mechanism for this transformation is illustrated in Scheme 5. Initially, in the presence of base, N-(benzyl oxy)-2-bromo-2-methylpropanamide 2a was transformed into intermediate 8 through elimination of one molecular HBr. In the meantime, with the release of molecule nitrogen, a carbene intermediate A was generated from aryl diazoacetates 1 upon the irradiation with blue LEDs. When the reaction was performed in 1,4-dioxane, trapping of the carbene species A by

![Scheme 3 Substrate scope with 1,4-dioxane as the solvent. Reaction conditions: 1 (0.2 mmol), 2 (0.3 mmol), KO'Bu (0.24 mmol), 1,4-dioxane (2 mL), r.t., 30W blue LEDs (λ = 440–450 nm), 14 h. Isolated yield.](https://example.com/scheme3.png)

![Scheme 4 Mechanistic studies.](https://example.com/scheme4.png)
the intramolecular elimination product 8 afforded the N–H insertion product 4. However, when THF was employed as the reaction solvent, an active oxonium ylide intermediate 9 would be generated. Then, intramolecular nucleophilic attack of the nitrogen anion B on the intermediate 9 would lead to the formation of intermediate C, which further delivered the final product 3.

Conclusions

In summary, a visible light promoted N–H functionalization of O-substituted hydroxamic acids with diazo esters under mild conditions was developed. The reactions proceeded efficiently to afford two series of N–H functionalized products of O-substituted hydroxamic acids in moderate to excellent yields with good functional group compatibility. When 1,4-dioxane was applied as the solvent, N–H insertion of the photogenerated free carbene species into hydroxamic acid derivatives occurred directly. While, when the reaction was performed in THF, it was found that THF can participate in the reaction system through a formation of an active oxonium ylide intermediate. Taken THF as a covalent linker, this strategy can be applied in medicinal chemistry to providing a new approach for antibody-drug conjugation.14

Conflicts of interest

There are no conflicts to declare.

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Notes and references


