

TiCl₄-Promoted Baylis-Hillman Reactions of Substituted 5-Isoxazolecarboxaldehydes with Cycloalkenones¹

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The Baylis-Hillman (BH) reaction of substituted 5-isoxazolecarboxaldehydes with cyclohexenone in the presence of TiCl₄ invariably lead to the formation of hemiacetals beside the BH adducts. A similar reaction in the presence of DABCO, DBU, or 3-HQN yielded minor quantities of phenols in addition to the usual BH adducts. Similar to 5-isoxazolecarboxaldehydes, the TiCl₄-mediated BH reaction of cyclohexenone with various benzaldehydes also furnishes hemiacetals in considerable yields. The reaction mechanism involving the formation of α -chloromethyl enone as an intermediate has been proposed. The synthesis of hemiacetals 5 and 14 from compound 4 in the presence of cyclohexenone and cyclopentenone, respectively, under acidic conditions indicates that enolization and aromatization of the cyclohexene ring are the key steps in the reaction mechanism.

Introduction

The Baylis-Hillman (BH) reaction is one of the most studied reactions in the last couple of years.² The synthetic utility of this carbon-carbon bond-forming reaction has been exploited both in solution^{3–30} and solid phase³¹ chemistry, since it offers a convenient route toward generation of array of multifunctional products,

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which can be selectively extended further. These products have also been utilized as the building blocks for natural products and biologically active compounds.³² However, the slow rate of the reaction has led to number of $reports^{\rm 33-58}$ of catalysts and conditions that lead to rate acceleration. Among these reports, the use of Lewis acids

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with or without various other additives in the reaction system is the most common choice for activating the carbonyl system. The use of Lewis acids in BH reactions at lower temperature in the presence of an additive furnishes either halo aldol^{44,46,50,53} or halo methyl enone⁴² as the major product while, at room temperature, the formation of the usual BH adduct has also been reported.^{35,41} However, recently Iwamura et al. reported⁵⁸ the formation of hemiacetal through aqueous workup during boron tribromide promoted BH reaction of pnitrobenzaldehyde with cyclohexenone. In an earlier observation, Li et al. too have reported⁴⁰ the formation of an unidentified side product (10%) during the TiCl₄mediated BH reaction of *p*-nitrobenzaldehyde and α , β -cycloalkenone. In the studies directed toward the BH reaction of 5-isoxazolecarboxaldehydes we have earlier reported that these substrates undergo fast reaction both in solution phase²⁹ and on solid support.^{31d} In our continued work in this area we have also carried out the BH reaction with α,β -unsaturated cyclic ketones in the presence of TiCl₄. We have observed that, under our reaction conditions when cyclohexenone was used as the activated enone, the hemiacetal appeared right from the onset of reaction along with the usual BH adduct. The details of our study are presented here.

Result and Discussion

The reactions of 3-substituted phenyl-5-isoxazolecarboxaldehydes (1a-d) were carried out by sequentially adding the 1.5 equiv of unsaturated ketone and 1.0 equiv of TiCl₄ to the appropriate solution of aldehyde in

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TABLE 1. Results of Baylis-Hillman Reaction of 3-Substituted Phenyl-5-isoxazolecarboxaldehyde in the **Presence of TiCl**₄

entry	R	alkene	time (h)	product (yield (%))
1 2 3 4 5 6 7	$C_{6}H_{5}$ 4-(CH ₃)C ₆ H ₄ 4-ClC ₆ H ₄ 4-(OCH ₂ C ₆ H ₅)C ₆ H ₄ C ₆ H ₅ 4-(CH ₃)C ₆ H ₄ 4-(CH ₃)C ₆ H ₄	cyclopentenone cyclopentenone cyclopentenone cyclopentenone cyclohexenone cyclohexenone cyclohexenone	1.5 1 1 2.2 1 0.6	2 (58), 3 (7) 2 (69), 3 (15) 2 (50), 3 (12) 2 (65), 3 (5) 4 (35), 5 (20) 4 (42), 5 (33) 4 (42), 5 (33)
8	$4-(OCH_2C_6H_5)C_6H_4$	cyclohexenone	2	4 (40), 5 (25)

dichloromethane at 0-5 °C under stirring, and the reaction was allowed to continue at the same temperature. In the presence of cyclopentenone the usual BH products (2a-d) were obtained in major yields while the α -chloromethyl enones (**3a**-**d**) were obtained in traces only. In contrast to this, when reactions were carried out in the presence of cyclohexenone, in addition to the usual BH adducts (4a-d), hemiacetals (5a-d) were obtained in moderate yields (Scheme 1). Within a short duration of time, the reactions of 5-isoxazolecarboxaldehydes with cycloalkenones in the presence of TiCl₄ went to completion (Table 1). We did not detect the presence of α -chloromethyl enone (6) in any of these reactions. It is appropriate to mention here that, during the workup, all reactions were quenched with saturated sodium bicarbonate solution. All these reactions were continuously monitored through TLC and ¹H NMR. The structure of the hemiacetal was confirmed on the basis of detailed 2D NMR spectroscopic studies. If the reactions were subjected to only aqueous workup and left for several hours as reported by Iwamura et al.,⁵⁸ we obtained the BH adduct (4) too, in addition to the hemiacetal (5) and the phenol (7).

We next examined different reaction conditions as an alteration to the general procedure of our BH reaction to evaluate and compare the amounts of hemiacetal and BH adduct formed (Table 2). During a study utilizing compound 1b as model, it was observed that if a chalcogenide such as dimethyl sulfide (0.1 equiv) was added



 TABLE 2.
 Variation of Yields during Baylis-Hillman Reaction with Cyclohexenone with Change in Reaction

 Conditions
 Conditions

entry	conditions	time (min)	product (yield (%))
1	cyclohexenone (2 equiv) + Me ₂ S (0.1 equiv) + TiCl ₄ (1 equiv), at $0-5$ °C	45	4 (64), 5 (31)
2	cyclohexenone (2 equiv) + TiCl ₄ (1 equiv), at $0-5$ °C	20	4 (48), 5 (30)
3	cyclohexenone (3 equiv) + TiCl ₄ (1 equiv), at $0-5$ °C	18	4 (50), 5 (28)
4	addition of TiCl ₄ done at $0-5$ °C and then reaction stirred at room temp	60	4 (39), 5 (25)

SCHEME 2



along with TiCl₄ (1.0 equiv) and cyclohexenone in the reaction (entry 1), the usual BH adduct (**4b**) was obtained in better yield while the yield of hemiacetal (**5b**) remain unaffected. Increasing the amount of cyclohexenone to 2 equiv (entry 2) or 3 equiv (entry 3) increased the rate of reaction though it did not significantly affect yields of BH adduct and hemiacetal. Escalation of the temperature of the reaction decreased yields of the final products (entry 4).

Interestingly, as we did not obtain the α -chloromethyl enone (6) in any of our reactions with cyclohexenone, we further explored various conditions under which it could be furnished. Since it has already been reported^{45,58} that the haloalkenones could be generated by reactions of BH adduct with hydrogen halide which is liberated in situ from the Lewis acid, we subjected compound 4b to reaction with HCl in dichloromethane for more than 24 h Unexpectedly, this reaction instead of giving α -chloromethyl enone (6) furnished the phenol (7b) exclusively in more than 70% yield. Similar to this reaction, if the compound **4b** was further stirred with only TiCl₄ in dichloromethane, the phenol (7b) was obtained in good yield. In contrast, if compound **2b** was treated with TiCl₄ or HCl, it led to formation of α -chloromethyl enone **3b** exclusively. In view of these results it was envisaged that compound 4 could afford hemiacetal when treated with cyclohexenone under acidic condition. Therefore, compound **4b** was reacted with 1.0 equiv of cyclohexenone in the presence of HCl for more than 24 h. This reaction as expected furnished the hemiacetal **5b** in 65% yields with minor quantities of phenol 7b (Scheme 2).

The reaction mechanism for the formation of hemiacetal is similar to the one proposed earlier (Scheme 3).⁵⁸ However in the view of various reactions carried out during our studies, it could be proposed that in the case of cyclohexenone also the α -chloromethyl enone (**6**) is formed but it is unstable and in the absence of cyclohexenone immediately transforms to intermediate **8** which furnished the phenol **7**. On the other hand, in the presence of excess of cyclohexenone the formation of hemiacetal is favored. It is likely that the intermediate

dienol (9) is formed through the enolization of the BH adduct 4, which undergoes Michael addition in the presence of cyclohexenone to form the diketone 10. This could be followed by chlorination of the intermediate 10 with TiCl₄ or HCl to afford **11**. On the other hand, it can also be proposed that the unstable α -chloromethyl enone (6) possibly adds up another cyclohexenone to furnish the similar intermediate 11. The subsequent removal of HCl from 11 leads to the diketone 12. The enol of this intermediate possibly provokes aromatization of the cyclohexane ring to furnish 13, which subsequently undergoes a cyclization to yield the hemiacetal 5. The facile aromatization of the cyclohexane ring might be the driving force toward the formation of hemiacetal. In principle, if the aromatization of the cyclohexenone is the key step, the TiCl₄- (or acid-) mediated reaction between the BH adduct 4 and other cycloalkenones would afford the corresponding hemiacetals but it will not be true for the BH adduct of any other alkenones. To ascertain this in a model reaction, compound 4b was reacted with cyclopentenone in the presence of TiCl₄ (or HCl) under similar conditions (Scheme 3). As anticipated, this reaction led to the formation of analogous hemiacetal 14b (Scheme 4). On the other hand, compound **2b** under same condition failed to react with cyclohexenone and afforded compound **3b** as the only product. On the basis of these findings, it could be proposed that the α -halomethyl enone could be a common product in Lewis acid promoted BH reactions but in the case of cyclohexenone under acidic condition it is unstable and transforms to furnish either phenol or hemiacetal.

To confirm the role of acid toward the formation of phenol during reactions of cyclohexenone it was considered appropriate to carry out similar reactions of 5-isoxazolecarboxaldehyde in the presence of DABCO, DBU, or 3-HQN. To the best of our knowledge, previous to this work there existed only two reports^{56,60} where the authors

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SCHEME 3



SCHEME 4



SCHEME 5



In light of these observations we also revisited the TiCl₄-mediated BH reactions of various other aromatic aldehydes with cyclohexenone. It was observed that under our reaction conditions, besides the BH adducts (**16a**-**e**), hemiacetals (**17a**-**d**) were formed in moderate yields invariably with all benzaldehydes, but no such product was observed for pyridinecarboxaldehyde (Scheme 6). However, the yield of hemiacetal was better in the benzaldehydes bearing a phenyl group with electron-withdrawing substitution (Table 3).

Conclusion

In conclusion, we have described the detailed synthetic and mechanistic aspects of the formation of hemiacetal during $TiCl_4$ -promoted BH reaction of substituted 5-isoxazolecarboxaldehydes with cyclohexenone. This holds true for reactions of other aromatic aldehydes also,

have carried out the BH reaction of cyclohexenone in the presence of base reporting the formation of the usual BH adduct. To our surprise, these reactions led to phenols (7a-d) in 19–25% yields besides the normal BH adducts (4a-d) in 59–65% yields (Scheme 5). These results suggest that during the reactions of TiCl₄ though the acidic medium of the reaction mixture might be responsible for the dehydration leading to a 1,5-shift for aromatization by enolization of the usual BH adduct, the phenol can also be produced by some other mechanism.



a	4-CF ₃ -C ₆ H ₄
e	3-C ₅ H ₅ N

 TABLE 3.
 Reaction of Various Aldehydes with

 Cyclohexenone in the Presence of TiCl₄

entry	R	time (h)	product (yield (%))
1	C ₆ H ₅	24	16a ⁶⁰ (15), 17a (7)
2	$4-(CH_3)C_6H_4$	36	16b ⁶⁰ (10), 17b (10)
3	$4 - (NO_2)C_6H_4$	2.15	16c ^{35,41} (48), 17c ⁵⁸ (30)
4	$4 - (CF_3)C_6H_4$	2.30	16d ⁶¹ (50), 17d (28)
5	pyridine-3-	1.3	16 (58)

though the reaction times were higher. The yields of such hemiacetals are significant for aldehydes bearing an electron-withdrawing group on the phenyl ring. It is confirmed through our studies that a slight excess of cyclohexenone and the acidic medium of the reaction is sufficient for the generation of hemiacetal. During this study we have observed that minor quantities of corresponding phenols are also formed during the basepromoted BH reaction of aldehyde with cyclohexenone. This indicates that it is not only the acidic condition that is responsible for the generation of phenol but also some other mechanism in the presence of base that could form phenol.

Experimental Section

General Methods. Reactions were run in oven-dried glassware, and dried dichloromethane was prepared by distillation over P_2O_5 . All column chromatography was carried on flash silica gel (230–400 mesh) using distilled solvents. Melting points are uncorrected and were determined in capillary tubes on a hot stage apparatus containing silicon oil. IR spectra were recorded using an FTIR spectrophotometer. ¹H NMR and ¹³C NMR spectra were run in CDCl₃ and recorded on either a 300 or a 200 MHz FT spectrometer, using TMS as an internal standard (chemical shifts in δ values, *J* in Hz). The EIMS and FABMS were recorded through direct injections in an LCMS system. Elemental analyses were performed on a microanalyzer.

General Procedure for Reactions of 3-Substituted Phenyl-5-isoxazolecarboxaldehydes with Cyclopentenone. To a stirred solution of the appropriate compound from 1a-d (0.5 mmol) and cyclopentenone (1.06 mmol) in dry dichloromethane (DCM) (1.5 mL) was added TiCl₄ (89.3 μ L, 0.5 mmol in 0.5 mL of DCM) at 0-5 °C. The stirring was continued at the same temperature for the time given in Table 1 (entries 1-4). Thereafter, the reaction mixture was quenched by addition of saturated aqueous NaHCO₃ solution and stirred further for 30 min. The inorganic precipitate was filtered out with a Celite bed using DCM. The organic layer was separated, dried over Na₂SO₄, and evaporated under reduced pressure to furnish an oily residue. Purification of the residue by column chromatography using hexane–ethyl acetate (95:05, v/v) furnished the α -chloromethyl enones (**3a**–**d**), while further elution with 65:35 (v/v) ratio of the same solvent yielded the BH adducts as solids (**2a**–**d**).

2b: 69% as a pale yellow solid, mp 88–90 °C; IR (KBr) 1689, 3362 cm⁻¹; ¹H NMR (CDCl₃) δ 2.39 (s, 3H, CH₃), 2.49–2.54 (m, 2H, CH₂), 2.68–271 (m, 2H, CH₂), 3.98 (d, 1H, J = 6.3 Hz, OH), 5.76 (d, 1H, J = 6.0 Hz, CH), 6.60 (s, 1H, =CH), 7.25 (d, 2H, J = 8.0 Hz, Ar H), 7.62 (t, 1H, J = 1.8 Hz, =CH), 7.68 (d, 2H, J = 8.0 Hz, Ar H); mass (EI) m/z 269 (M⁺, 45), 158 (100). Anal. Calcd for C₁₆H₁₅NO₃: C, 71.36; H, 5.61; N, 5.20. Found: C, 71.54; H, 5.77; N, 5.1.

3b: 15% as white solid, mp 118–120 °C; IR (KBr) 1708 cm⁻¹; ¹H NMR (CDCl₃) δ 2.41 (s, 3H, CH₃), 2.45–259 (m, 3H, CH₂), 2.77–2.90 (m, 1H, CH₂), 5.70–5.72 (m, 1H, CHCl), 6.95 (s, 1H, =CH), 7.26–7.30 (m, 3H, =CH and Ar H), 7.71 (d, 2H, J= 8.0 Hz, Ar H); mass (FAB+) *m*/*z* 288 (M⁺ + 1). Anal. Calcd for C₁₆H₁₄ClNO₃: C, 66.78; H, 4.90; N, 4.86. Found: C, 66.74; H, 5.07; N, 4.67.

General Procedure for TiCl₄-Promoted Reactions of 3-Substituted Phenyl-5-isoxazolecarboxaldehydes with **Cyclohexenone**. To a stirred solution of the appropriate compound from 1a-d (0.5 mmol) and cyclohexenone (1.0 mmol) in dry DCM (1.5 mL) was added TiCl₄ (89.3 μ L, 0.5 mmol in 0.5 mL of DCM) at 0-5 °C. The stirring was continued at same temperature for the time given in Table 1 (entries 5-8). Thereafter, the reaction mixture was quenched with saturated aqueous NaHCO₃ solution and stirred further for 30 min. The precipitate of inorganic material was removed by filtration through Celite using DCM. The organic layer was separated, dried over Na₂SO₄, and evaporated to furnish an oily residue. This residue was purified by column chromatography using hexane-ethyl acetate (90:10, v/v), which furnished the hemiacetal (5a-d) as pale yellow solids, while further elution with a 70:30 (v/v) solvent mixture furnished the BH adduct (4a-d) as oil or solid.

4b: 42% as pale yellow solid, mp 108–110 °C; IR (KBr) 1653, 3377 cm⁻¹; ¹H NMR (CDCl₃) δ 2.04 (quintet, 2H, J = 6.2 Hz, CH₂), 2.39 (s, 3H, CH₃), 2.43–2.53 (m, 4H, 2 × CH₂), 5.56 (s, 1H, CH), 6.58 (s, 1H, =CH), 7.01 (t, 1H, J = 4.0 Hz, =CH), 7.24 (d, 2H, J = 8.0 Hz, Ar H), 7.68 (d, 2H, J = 8.0 Hz, Ar H); mass (EI) m/z 283 (M⁺, 44), 199 (80), 158 (100). Anal. Calcd for C₁₇H₁₇NO₃: C, 72.06; H, 6.04; N, 4.94. Found: C, 71.77; H, 6.14; N, 4.78.

5b: 33% as pale yellow oil; IR (neat) 3352 cm⁻¹; ¹H NMR (CDCl₃) δ 1.54–1.77 (m, 5H, 2 × CH₂ and 1H other CH₂), 1.97–2.08 (m, 3H, 1 CH₂ and 1H of other CH₂), 2.36 (s, 3H, CH₃), 3.19 (t, 1H, J = 3 Hz, CH), 4.00 and 4.11 (2d, each 1H, J = 10 Hz, benzylic CH₂), 6.20 (s, 1H, =CH), 6.79 (t, 1H, J = 7.4 Hz, =CH), 6.95 (dd, 1H, $J_1 = 1.5$ Hz, $J_2 = 7.4$ Hz, Ar H), 7.05 (dd, $J_1 = 1.5$ Hz, $J_2 = 7.4$ Hz, Ar H), 7.05 (dd, $J_1 = 1.5$ Hz, $J_2 = 7.4$ Hz, Ar H), 7.62 (d, 2H, J = 8.0 Hz, Ar H); ¹³C NMR (CDCl₃, 75.6 MHz) δ 21.78 (CH₃), 22.69 (CH₂), 38.68 (CH₂) 6.795 (CH), 100.27 (CH=), 126.48 (C), 127.12 (2 × CH), 129.96 (2 × CH), 137.51 (C), 140.52 (C), 149.67 (CH), 162.79 (C), 173.25 (C), 200.42 (CO); mass (FAB+) *m*/*z* 362 (M⁺ + 1). Anal. Calcd for C₂₃H₂₃NO₃: C, 76.43; H, 6.41; N, 3.87. Found: C, 76.12; H, 6.44; N, 4.05.

General Procedure for TiCl₄-Promoted Reactions of Compound 4b with Cycloalkenones. To a stirred solution of compound 4b (0.35 mmol) and appropriate cycloalkenone (1.0 mmol) in dry DCM (1.5 mL) was added TiCl₄ (38 μ L, 0.34 mmol in 0.5 mL of DCM) at 0–5 °C. The reaction was continued at the same temperature for 1 h, and then it was quenched with saturated aqueous NaHCO₃ solution and stirred further for 30 min. The precipitate of inorganic material was removed by filtration through Celite using DCM. The organic layer was separated, dried over Na₂SO₄, and evaporated to furnish an oily residue. The residue obtained from the reaction of cyclopentenone was purified by column chromatography using hexane–ethyl acetate (95:5, v/v) that furnished the phenol **7b** in 7% yield, while elution with 90:10 (v/v) of the same solvent yielded the hemiacetal (**14b**) in 18% yield as a pale yellow oil. In the case for the residue from the reaction of cyclohexenone also, elution with hexane–ethyl acetate (95:5, v/v) gave the phenol **7b** in 19% yield and further elution with 90:10 (v/v) hexane–ethyl acetate afforded the hemiacetal (**5b**) in 22% yield. Elution with a mixture of 70:30 (v/v) of the same solvents furnished the unreacted starting material in 52% yields. (This reaction if continued for more than 24 h did not give any starting material.)

14b: 18% as pale yellow oil; IR (neat) 3376 cm⁻¹; ¹H NMR (CDCl₃) δ 1.59–1.69 (m, 2H, CH₂), 1.99–2.08 (m, 2H, CH₂), 2.29–2.41 (m, 4H, 1 CH₃ and 1H of CH₂), 2.67 (dd, 1H, $J_1 =$ 7.5 Hz, $J_2 =$ 17.5 Hz, 1H of CH₂), 3.67–3.72 (m, 1H, CH), 4.12 (s, 2H, benzylic CH₂), 6.21(s, 1H, =CH), 6.93 (t, 1H, J = 8.0 Hz, Ar H), 7.61 (d, 2H, J = 8.0 Hz, Ar H); mass (FAB+) *m*/*z* 348 (M⁺ + 1). Anal. Calcd for C₂₂H₂₁NO₃: C, 76.27; H, 5.81; N, 4.04. Found: C, 76.12; H, 6.04; N, 4.05.

General Procedure for HCl-Mediated Reactions. Method A. To a stirred solution of compound **4b** (0.1 mmol) and appropriate cycloalkenone (0.1 mmol) in dry DCM (1.5 mL) was added HCl (30 μ L, 0.36 mmol) at room temperature. The reaction was continued for 24 h, dichloromethane was evaporated, and the residue was extracted with ethyl acetate (2 × 10 mL). The organic layers were combined, dried over anhydrous Na₂SO₄, and evaporated under vacuum. The residues from cyclopentenone and cyclohexenone were subjected to column chromatography, and the respective products (**5b** and **14b**) were isolated as described above for TiCl₄-mediated reactions.

Method B. To a stirred solution of appropriate compound from **2b** or **4b** (0.1 mmol) in dry DCM (1.5 mL) was added HCl (30 iL, 0.36 mmol) at room temperature. The reaction was continued for 24 h, DCM was evaporated, and the residue was extracted with ethyl acetate (2×10 mL). The organic layers were combined, dried over anhydrous Na₂SO₄, and evaporated under vacuum. The α -chloromethyl enone (**3b**) in the case of **2b** or phenol **7b** in the case of **4b** was isolated by column chromatography as described above.

General Procedure for DABCO-, DBU-, or 3-HQN-Mediated Reactions of 3-Substituted Phenyl-5-isoxazolecarboxaldehydes with Cyclohexenone. To a prestirred mixture of DABCO, DBU, or 3-HQN (0.15 mmol) and cyclohexenone (0.15 mL, 1.5 mmol) was added the appropriate aldehyde from 1a-d, and the stirring was continued at room temperature for 18 h. Thereafter, the reaction mixture was extracted with ethyl acetate (2 × 15 mL) and washed with water (15 mL). The organic layers were pooled, dried over Na₂-SO₄, and evaporated under reduced pressure to furnish an oily residue that was purified by column chromatography. Elution with hexane–ethyl acetate (90:10, v/v) gave the phenols (7a-d) as white solids, while further elution with 70:30 (v/v) solvent yielded the BH adduct as a light yellow solid.

7b: 25% as a white solid, mp 108–110 °C; IR (KBr) 3432 cm⁻¹; ¹H NMR (CDCl₃) δ 2.35 (s, 3H, CH₃), 4.01 (d, J=10 Hz, 1H of benzylic CH₂), 4.13 (d, J=10 Hz, 1H of benzylic CH₂), 6.21 (s, 1H, =CH), 6.81–6.93 (m, 2H, Ar H), 7.10–7.28 (m, 4H, Ar H), 7.62 (d, 2H, J=8.0 Hz, Ar H); ¹³C NMR (CDCl₃, 75.6 MHz) δ 21.4 (CH₃), 27.7 (CH₂), 99.8 (CH), 115.7 (CH), 121.1 (CH), 122.7 (C), 126.7 (2 × CH), 128.6 (CH), 129.5 (2 × CH), 130.9 (CH), 139.9 (C), 153.7 (C), 162.5 (C), 1732.2 (C); mass (FAB+) *m*/*z* 266 (M⁺ + 1). Anal. Calcd for C₁₇H₁₇NO₃: C, 76.95; H, 5.69; N, 5.28. Found: C, 76.67; H, 6.04; N, 5.20.

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Supporting Information Available: Physical and spectroscopic data for compounds **2a,c,d**, **3a,c,d**, **4a,c,d**, **5a,c,d**, **7a,c**, **16e**, and **17a–c**, ¹H NMR spectral charts of compounds **2b**, **3b**, **4b**, **5b**, **7b**, **14b**, and **17**, ¹³C NMR spectral charts of compounds **4b** and **5b**, and 2D COSY (HMQC and HMBC) charts used for characterization of hemiacetal **5b**. This material is available free of charge via the Internet at http://pubs.acs.org.

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