Synthesis of Substituted Indenes from Isovanillin via Claisen Rearrangement and Ring-closing Metathesis

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A new synthesis of substituted indenes was studied. Based on Claisen rearrangement, Wittig reaction and ring-closing metathesis (RCM), a series of substituted indenes was synthesized from isovanillin in good yields.

Keywords: Isovanillin; Claisen rearrangement; RCM; Indenes.

INTRODUCTION

Indenes, playing an important role as structural units or starting material for the construction of some important organic compounds, have been well recognized.\textsuperscript{1} For example, sulindac is an anti-inflammatory drug which has an indene moiety in the structure.\textsuperscript{2} Recently indenes have been the subject of extensive studies due to their biological activities, which include antibacterial activity,\textsuperscript{3a} antiviral activity,\textsuperscript{3b} antifungal activity,\textsuperscript{3c} apoptosis activity,\textsuperscript{3d} and cytotoxicity to hepatic tumors.\textsuperscript{3e} However, only a few indenes with functional substituents have been described. They include (i) a \(\text{[1,5]}\) H shift of isoindene;\textsuperscript{4a} (ii) a reaction of indanone tosylhydrazone with \(n\)-ButLi;\textsuperscript{4b} (iii) a flash vacuum thermolysis of 1,3,8-nonatriyne;\textsuperscript{4c} (iv) a cocondensation of arc generated carbon vapor with cyclooctatetraene at 77 K;\textsuperscript{4d} and (v) a traditional method, by dehydration of corresponding indanol with acid.\textsuperscript{4e} Even though, there still exist some drawbacks such as tedious reaction conditions, commercially unavailable starting materials, and low yields.\textsuperscript{5} Thus, it is necessary to develop more practical and efficient method for the preparation of substituted indenes. Since 1995 Grubbs et al.\textsuperscript{6} discovered a novel ruthenium-benzylidine carbene complex (Grubbs cat.) catalyzed ring closing olefin metathesis (RCM), it has been widely and rapidly applied in organic synthesis in many aspects.\textsuperscript{7} Until the present no attention has been paid to apply this RCM reaction to indenes chemistry.

Recently we reported a novel method for the synthesis of substituted naphthalenes.\textsuperscript{8} It turned out to be an efficient method for introduction of functional substituents in naphthalenes. In continuation of studies, herein we would like to disclose a versatile and novel strategy for the synthesis of poly-substituted indenes by the following protocols (Scheme I).

RESULTS AND DISCUSSION

As in the general procedure and in our previous report,\textsuperscript{8} isovanillin (1) was alkylated with various allylic halides such as...
as allyl bromide and 1-bromo-2-butene in anhydrous acetone in the presence of potassium carbonate to give various allylisovanillins (2a-b) in yields of 88-92%, respectively. Followed by Claisen rearrangement of these allylisovanillins (2a-b), the different ratios of ortho and para products was given. Subsequently the products of Claisen rearrangement, 3a, 3b, and 4b, were alkylated as in the general procedure with various alkyl halides such as methyl iodide, ethyl iodide, and benzyl bromide in anhydrous acetone in the presence of potassium carbonate to give various allyldimethoxyindenes (5a-f) and allyldimethoxy-1-methylindenes (6a-c) in yields of 80-98%, respectively. The structures of 5a-f, and 6a-c, are supported by their 1H and 13C NMR spectra. Following treatment of 5a-f and 6a-c with methyl triphenylphosphorus bromide and potassium tert-butoxide to undergo Wittig reaction, the desired allyl vinylbenzenes 7a-f, and 8a-c, in yields of 76-90% were given. The chemical elucidation of 7a-f and 8a-c can be confirmed by examining the new formation of a vinyl group or the disappearance of a formyl group in 1H-NMR spectra compared to the starting materials; their 1H-NMR spectra are summarized in Table 2. Further structural proof for the indenes substructure came from the 2D NMR spectroscopy. The NOESY spectrum of indenes 10c shows the relatively strong intensity of (a) H-1 ↔ H-2, H-7; (b) OMe ↔ H-7; (c) OCH3Ph ↔ H-4, as allyl bromide and 1-bromo-2-butene in anhydrous acetone in the presence of potassium carbonate to give various allylisovanillins (2a-b) in yields of 88-92%, respectively. Followed by Claisen rearrangement of these allylisovanillins (2a-b), the different ratios of ortho and para products was given. Subsequently the products of Claisen rearrangement, 3a, 3b, and 4b, were alkylated as in the general procedure with various alkyl halides such as methyl iodide, ethyl iodide, and benzyl bromide in anhydrous acetone in the presence of potassium carbonate to give various allyldimethoxyindenes (5a-f) and allyldimethoxy-1-methylindenes (6a-c) in yields of 80-98%, respectively. The structures of 5a-f, and 6a-c, are supported by their 1H and 13C NMR spectra. Following treatment of 5a-f and 6a-c with methyl triphenylphosphorus bromide and potassium tert-butoxide to undergo Wittig reaction, the desired allyl vinylbenzenes 7a-f, and 8a-c, in yields of 76-90% were given. The chemical elucidation of 7a-f and 8a-c can be confirmed by examining the new formation of a vinyl group or the disappearance of a formyl group in 1H-NMR spectra compared to the starting materials; their 1H-NMR spectra are summarized in Table 2. Further structural proof for the indenes substructure came from the 2D NMR spectroscopy. The NOESY spectrum of indenes 10c shows the relatively strong intensity of (a) H-1 ↔ H-2, H-7; (b) OMe ↔ H-7; (c) OCH3Ph ↔ H-4,
OCH₂Ph, cross-peaks point to a short distance between these proton (Fig. 1). The other NOESY spectrum of 9c shows cross-peaks of (a) H-1 ↔ OCH₂Ph, H-2; (b) OMe ↔ H-5. Thus, the indenes structure 9a-f and 10a-c are characterized by ¹H-NMR, ¹³C-NMR, and NOESY spectrum. Due to the fact only one set of signals in both ¹H-NMR and ¹³C-NMR spectra was found in the structures of indenes 9a-f and 10a-c, it means no other isomer was found in our reaction condi-

Table 1. The Vinyl Protons of Allylvinylbenzenes 7a-f and 8a-c in ¹H-NMR Spectra

<table>
<thead>
<tr>
<th>Entry</th>
<th>Hₐ (dd, J = 11.0, 1.5 Hz)</th>
<th>Hₐ (dd, J = 17.5, 1.5 Hz)</th>
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<tr>
<td>7a</td>
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<tr>
<td>7b</td>
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<tr>
<td>7c</td>
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<td>7d</td>
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<td>5.44</td>
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<td>7e</td>
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<tr>
<td>8c</td>
<td>5.14</td>
<td>5.41</td>
<td>6.86</td>
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Table 2. The Chemical Shifts of Substituted Indenes 9a-f and 10a-c in ¹H-NMR Spectra

<table>
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<th>Entry</th>
<th>R₁</th>
<th>R₂</th>
<th>H-1 (dd, J = 2.0, 0.8 Hz)</th>
<th>H-2 (dt, J = 5.5, 2.0 Hz)</th>
<th>H-3 (dt, J = 5.5, 0.8 Hz)</th>
<th>H-4 (d, J = 8.0 Hz)</th>
<th>H-5 (d, J = 8.0 Hz)</th>
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<td>9a</td>
<td>H</td>
<td>Me</td>
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<td>6.43 (dt, J = 5.5, 2.0 Hz)</td>
<td>6.79 (dt, J = 5.5, 0.8 Hz)</td>
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<td>H</td>
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<td>6.34 (dt, J = 5.5, 2.0 Hz)</td>
<td>6.73 (dt, J = 5.5, 0.8 Hz)</td>
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<td>9c</td>
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<td>6.32 (dt, J = 5.5, 2.0 Hz)</td>
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<td>Me</td>
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<td>6.29 (dd, J = 5.5, 2.0 Hz)</td>
<td>6.61 (dd, J = 5.5, 0.8 Hz)</td>
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<td>Et</td>
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<td>6.44 (dt, J = 5.5, 2.0 Hz)</td>
<td>6.79 (dt, J = 5.5, 0.8 Hz)</td>
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<td>6.78 (dt, J = 5.5, 0.8 Hz)</td>
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<td>7.01 (d, J = 8.0 Hz)</td>
<td>7.26 (d, J = 8.0 Hz)</td>
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tions. The results are compiled in Table 3.

In conclusion, based on Claisen rearrangement, Wittig reaction, and RCM, we have established a straightforward, versatile, and novel route to transform isovanillin into a number of potential substituted indenes, and the overall yields range from 65% to 76%, calculated from compound 3 or 4 (Table 3). The sequence works well for substituted alkoxyindenes such as 7-alkoxy-6-methoxyindenes, 7-alkoxy-6-methoxy-1-methylindenes, and 5-alkoxy-6-methoxyindenes. Among these products, many have not been previously reported. The application of our synthetic strategy to some potential compounds is currently in progress in our laboratory.

EXPERIMENTAL

Melting points (Yanaco micro melting-point apparatus) are uncorrected. $^1$H-NMR and $^{13}$C-NMR spectra were obtained on a Varian Gemini-300 or Varian Unity plus 400 or Varian Unity Inova 500 Spectrometer. Chemical shifts are measured in parts per million with respect to TMS. Mass spectra were recorded on a Chem/hp/middle instrument. The high-resolution mass spectra were performed on a JEOL JMS SX/SX 102A. Silica gel (230-400 mesh) for column chromatography and the precoated silica gel plate (60 F-254) for TLC were purchased from E. Merck Co. UV light (254 nm) was used to detect spots on TLC plates after development.

3-Hydroxy-4-methoxybenzaldehyde (isovanillin) (1) purchased from TCI (Tokyo Kasei Industry) was used directly without purification. Grubbs catalyst was purchased from Fluca Company.

General procedure for the preparation of vinylbenzenes (7a-f) and (8a-c)

To a stirred suspension of methyl triphosphonium bromide (2.0 g, 5.5 mmol) in dry THF (20 mL) at 0 °C, the powder of potassium tert-butoxide (0.6 g, 5.5 mmol) was added under dried nitrogen, in several portions over 5 minutes. After 10 min. of addition, the yellowish white suspension was formed, which was respectively added dropwise with aldehydes 5a-f (5 mmol) or 6a-c (5 mmol) in THF (20 mL). The suspension was continually stirred for 2-3 h until the aldehyde was consumed completely under TLC (EA/n-hexane = 1/6) monitoring, and then was concentrated under vacuum. The residue was added with water (20 mL), and extracted with ethyl acetate (15 mL × 5). The organic layer was washed with brine, and then dried with anhydrous MgSO$_4$, and then filtered. The filtrate was concentrated under vacuum to give a
pale yellow residue. Finally the given residue was subjected to column chromatography (n-hexane/EA = 8/1) to afford pure o-allyl vinylbenzenes 7a-f and 8a-c in good yields.

2-Allyl-3,4-dimethoxy-1-vinylbenzenes (7a)

Pure 7a (0.93 g, 83%) was obtained as pale yellow liquid; Rf 0.65 (EA/n-hexane = 1/7); 1H NMR (CDCl3, 500 MHz) δ 3.51 (ddd, J = 6.0 Hz, 1.8 Hz, 1.8 Hz, 2H, CH2=CHCH2Ar), 3.80, 3.87 (each s, 3H, OCH3), 4.92 (ddd, J = 17.0 Hz, 3.3 Hz, 1.8 Hz, 1H, CH3=CHCH2Ar), 5.01 (ddd, J = 10.3 Hz, 3.3 Hz, 1.8 Hz, 1H, CH3=CHCH2Ar), 5.18 (dd, J = 11.0 Hz, 1.5 Hz, 1H, CH3=CHAr), 5.54 (dd, J = 17.5 Hz, 1.5 Hz, 1H, CH3=CHAr), 5.97 (dd, J = 17.0 Hz, 10.3 Hz, 6.0 Hz, 1H, CH2=CHCH2Ar), 6.80 (d, J = 8.5 Hz, 1H, ArH), 6.85 (ddd, J = 17.5 Hz, 11.0 Hz, 1H, CH2=CHAr), 7.25 (d, J = 8.5 Hz, 1H, ArH); 13C NMR (CDCl3, 125 MHz) δ 30.15 (CH2=CHCH2Ar), 55.64, 60.81 (each, OCH3), 110.40, 113.97, 115.18, 121.27, 130.72, 131.24, 134.34, 136.68, 146.92, 152.99; EI-MS (70 eV) m/z (rel. intensity, %): 204 (M+, 93), 189 (80.71), 176 (98.49), 174 (66.13), 173 (44.59), 159 (45.59), 158 (100), 131 (48.50), 129 (88.28), 128 (57.57), 115 (74.05), 91 (38.93); HRMS caleld for C13H20O2: 204.1150. Found: 204.1152.

2-Allyl-3-ethoxy-4-methoxy-1-vinylbenzene (7b)

Pure 7b (0.96 g, 80%) was obtained as pale yellow liquid; Rf 0.70 (EA/n-hexane = 1/7); 1H NMR (CDCl3, 500 MHz) δ 1.37 (t, J = 7.0 Hz, 3H, OCH2CH3), 3.52 (ddd, J = 5.9 Hz, 1.8 Hz, 1.8 Hz, 2H, CH2=CHCH2Ar), 3.84 (s, 3H, OCH3), 3.98 (q, J = 7.0 Hz, 2H, OCH2CH3), 4.91 (ddd, J = 17.0 Hz, 3.8 Hz, 1.8 Hz, 1H, CH3=CHCH2Ar), 5.00 (ddd, J = 10.3 Hz, 3.8 Hz, 1.8 Hz, 1H, CH3=CHCH2Ar), 5.17 (dd, J = 11.0 Hz, 1.5 Hz, 1H, CH3=CHAr), 5.53 (ddd, J = 17.5 Hz, 1.5 Hz, 1H, CH3=CHAr), 5.95 (ddd, J = 17.0 Hz, 10.3 Hz, 5.9 Hz, 1H, CH3=CHCH2Ar), 6.79 (d, J = 8.5 Hz, 1H, ArH), 6.86 (dd, J = 17.5 Hz, 11.0 Hz, 1H, CH2=CHAr), 7.24 (d, J = 8.5 Hz, 1H, ArH); 13C NMR (CDCl3, 125 MHz) δ 15.65 (OCH2CH3), 30.32 (CH2=CHCH2Ar), 55.62 (OCH3), 68.82 (OCH2CH3), 110.31, 113.80, 115.06, 121.06, 130.65, 131.35, 134.45, 136.70, 146.14, 152.40; EI-MS (70 eV) m/z (rel. intensity, %) 218 (M+, 44.73), 203 (66.16), 190 (35.80), 189 (100), 188 (76.60), 175 (39.85), 174 (51.61), 173 (55.78), 172 (88.06), 159 (45.18), 158 (44.36), 145 (47.87), 143 (52.31), 129 (47.51), 115 (91.24), 91 (35.00); HRMS caleld for C14H14O2: 218.1307. Found: 218.1307.

3-Ethoxy-4-methoxy-2-(1-methyl-2-propenyl)-1-vinylbenzene (7e)

Pure 7e (0.98 g, 77%) was obtained as pale yellow liquid; Rf 0.78 (EA/n-hexane = 1/7); 1H NMR (CDCl3, 500 MHz) δ 1.38 (t, J = 7.0 Hz, 3H, OCH2CH3), 1.41 (d, J = 7.5 Hz, 3H, CH3=CHCH2Ar), 3.84 (s, 3H, OCH3), 3.98 (q, J = 7.0 Hz, 2H, OCH2CH3), 4.22 (m, 1H, CH2=CHCH2Ar), 6.82 (d, J = 8.5 Hz, 1H, ArH), 6.85 (ddd, J = 17.5 Hz, 11.0 Hz, 1H, CH2=CHAr), 7.27 (d, J = 8.5 Hz, 1H, ArH), 7.31-7.47 (m, 5H, OCH2C6H5); 13C NMR (CDCl3, 125 MHz) δ 30.32 (CH2=CHCH2Ar), 55.67 (OCH3), 74.70 (OCH2CH3), 110.45, 113.91, 115.22, 121.41, 127.73, 129.29, 130.73, 131.46, 134.35, 136.62, 137.93, 145.80, 152.38; EI-MS (70 eV) m/z (rel. intensity, %) 218 (M+, 51); 189 (26.14), 161 (8.10), 157 (7.02), 146 (5.41), 143 (12.30), 131 (8.31), 129 (13.46), 128 (9.82), 117 (6.49), 115 (10.93), 92 (8.20), 91 (100), 65 (8.26); HRMS caleld for C16H22O2: 280.1463. Found: 280.1465.
5.01 (dd, J = 17.0 Hz, 2.0 Hz, 1H, CH₃=CHCH=CHAr), 5.04 (dd, J = 10.3 Hz, 2.0 Hz, 1H, CH₃=CHCH=CHAr), 5.11 (dd, J = 11.0 Hz, 1.5 Hz, 1H, CH₃=CH=CHAr), 5.44 (dd, J = 17.5 Hz, 1.5 Hz, 1H, CH₃=CH=CHAr), 6.15 (dd, J = 17.0 Hz, 10.3 Hz, 5.0 Hz, 1H, CH₃=CHCH=CHAr), 6.77 (d, J = 8.5 Hz, 1H, ArH), 7.03 (dd, J = 17.5 Hz, 11.0 Hz, 1H, CH₃=CH=CHAr), 7.18 (d, J = 8.5 Hz, 1H, ArH); ¹³C NMR (CDCl₃, 125 MHz) δ 15.56 (OCH₃CH₃), 18.80 (CH₃=CHCH=CHAr), 34.90 (CH₃=CHCH=CHAr), 55.62 (OCH₃), 68.79 (OCH₃CH₃), 110.18, 112.83, 113.45, 122.36, 130.85, 135.93, 136.73, 142.82, 145.91, 152.53; EI-MS (70 eV) m/z (rel. intensity, %) 232 (M⁺, 45.35), 203 (47.03), 175 (34.06), 171 (29.38), 157 (91.16), 145 (27.65), 144 (25.66), 143 (100), 129 (56.41), 128 (56.06), 115 (64.87); HRMS calcd for C₁₄H₁₉O₂: 232.1463. Found: 232.1463.

3-Benzylxoye-4-methoxy-2-(1-methyl-2-propenyl)-1-vinylbenzene (7f)

Pure 7f (1.33 g, 82%) was obtained as pale yellow liquid; R₆ 0.77 (EA/n-hexane = 1/7); ¹H NMR (CDCl₃, 400 MHz) δ 1.35 (d, J = 7.2 Hz, 3H, CH₃=CHCH=CHAr), 3.86 (s, 3H, OCH₃), 4.24 (m, 1H, CH₃=CHCH=CHAr), 4.95 (s, 2H, OCH₂CH₃), 4.98 (dd, J = 17.2 Hz, 1.2 Hz, 1H, CH₃=CHCH=CHAr), 5.02 (dd, J = 10.6 Hz, 1.2 Hz, 1H, CH₃=CHCH=CHAr), 5.11 (dd, J = 11.0 Hz, 1.5 Hz, 1H, CH₃=CH=CHAr), 5.44 (dd, J = 17.5 Hz, 1.5 Hz, 1H, CH₃=CH=CHAr), 6.56 (dd, J = 17.2 Hz, 10.6 Hz, 5.0 Hz, 1H, CH₃=CHCH=CHAr), 6.80 (d, J = 8.8 Hz, 1H, ArH), 7.03 (dd, J = 17.5 Hz, 11.0 Hz, 1H, CH₃=CH=CHAr), 7.21 (d, J = 8.8 Hz, 1H, ArH), 7.31-7.47 (m, 5H, OCH₃CH₃); ¹³C NMR (CDCl₃, 125 MHz) δ 18.80 (CH₃=CHCH=CHAr), 34.93 (CH₃=CHCH=CHAr), 55.68 (OCH₃), 74.74 (OCH₂CH₃), 110.38, 112.94, 113.51, 122.72, 127.77, 128.07, 128.33, 130.97, 135.92, 136.89, 137.86, 142.74, 145.58; EI-MS (70 eV) m/z (rel. intensity, %) 294 (M⁺, 4.10), 203 (25.11), 175 (8.12), 171 (9.23), 157 (19.72), 133 (9.30), 128 (60.36); HRMS calcd for C₁₄H₁₉O₂: 232.1463. Found: 232.1463.

2-(2-Butenyl)-5-ethoxy-4-methoxy-1-vinylbenzene (8b)

Pure 8b (1.03 g, 81%) was obtained as pale yellow liquid; R₆ 0.63 (EA/n-hexane = 1/7); ¹H NMR (CDCl₃, 500 MHz) δ 1.46 (t, J = 7.0 Hz, 3H, OCH₂CH₃), 1.66 (dd, J = 6.5 Hz, 1.5 Hz, 1H, CH₃=CHCH=CHAr), 3.24 (d, J = 6.5 Hz, 2H, CH₂=CHCH₂Ar), 3.85 (s, 3H, OCH₃), 4.12 (q, J = 7.0 Hz, 2H, CH₂=CHAr), 5.18 (dd, J = 11.0 Hz, 1.5 Hz, 1H, CH₂=CHAr), 5.41 (dq, J = 14.0 Hz, 6.5 Hz, 1H, CH₂=CHCH₂Ar), 5.52 (dd, J = 17.5 Hz, 1.5 Hz, 1H, CH₂=CH=CHAr), 5.56 (dd, J = 14.0 Hz, 6.5 Hz, 1.5 Hz, 1H, CH₂=CHCH₂Ar), 6.64, 7.04 (each s, 1H, ArH); ¹³C NMR (CDCl₃, 125 MHz) δ 14.83 (OCH₂CH₃), 17.86 (CH₃=CHCH=CHAr), 35.84 (CH₃=CHCH=CHAr), 55.91 (OCH₃), 64.40 (OCH₂CH₃), 109.98, 112.79, 113.06, 126.07, 128.60, 129.71, 130.92, 134.16, 146.70, 149.15; EI-MS (70 eV) m/z (rel. intensity, %) 232 (M⁺, 63.50), 203 (39.19), 190 (38.13), 189 (81.99), 175 (100), 174 (37.40), 160 (33.04), 143 (32.32), 131 (33.48), 129 (43.16), 128 (49.94), 115 (50.74), 91 (33.62); HRMS calcd for C₁₅H₂₀O₂: 232.1463. Found: 232.1463.

5-Benzolxye-2-(2-butenyl)-4-methoxy-1-vinylbenzene (8c)

Pure 8c (1.26 g, 78%) was obtained as pale yellow liquid; R₆ 0.66 (EA/n-hexane = 1/7); ¹H NMR (CDCl₃, 500 MHz) δ 1.66 (dd, J = 6.5 Hz, 1.5 Hz, 3H, CH₂=CHCH₂Ar), 3.31 (d, J = 6.5 Hz, 2H, CH₂=CHCH₂Ar), 3.88 (s, 3H, OCH₃), 5.14 (dd, J = 11.0 Hz, 1.5 Hz, 1H, CH₂=CHAr), 5.15 (s, 2H, OCH₂CH₃), 5.41 (dq, J = 15.1 Hz, 6.5 Hz, 1H, CH₂=CHCH₂Ar), 5.41 (dd, J = 17.5 Hz, 1.5 Hz, 1H, CH₂=CH=CHAr), 5.54 (dd, J = 15.1 Hz, 6.5 Hz, 1.5 Hz, 1H, CH₂=CHCH₂Ar), 6.66, 7.06 (each s, 1H, ArH), 6.86 (dd, J = 17.5 Hz, 11.0 Hz, 1H, CH₂=CHAr), 7.31-7.46 (m, 5H, OCH₂CH₃); ¹³C NMR (CDCl₃, 125 MHz) δ 17.88 (CH₃=CHCH=CHAr), 35.87 (CH₃=CHCH=CHAr), 56.00 (OCH₃), 71.30 (OCH₂CH₃), 111.44, 113.11, 113.21, 126.151, 127.40, 128.70, 128.50, 128.66, 129.64, 131.54, 133.99, 137.32, 146.63, 149.54; EI-MS (70 eV) m/z (rel. intensity, %) 294 (M⁺, 17.26), 203 (39.72), 175 (16.19), 143 (19.72), 133 (9.30), 1129 (9.80), 128 (21.41), 117 (9.24), 115 (15.52); HRMS calcd for C₁₅H₂₀O₂: 294.1620. Found: 294.1620.
General procedure for preparation of indenes (9a-f) and (10a-c)

Compound 7a-f or 8a-c (1 mmol) dissolved in anhydrous CH2Cl2 (20 mL), was added with Grubbs catalyst (5% mol). The mixture was stirred for 2 h at ambient temperature under dry argon. Finally the solvent was removed under reduced pressure, and the residue was subjected to a silica gel column (5:1 hexane/MTBE) or to distill under vacuum to give 9a-f, and 10a-c respectively.

6,7-Dimethoxyindene (9b)

Pure 9a (0.17 g, 92%) was obtained as colorless liquid; Rf 0.76 (EA/hexane = 1/7); 1H NMR (CDCl3, 300 MHz) δ 3.64 (dd, J = 2.0 Hz, 0.8 Hz, H-1), 3.82 (s, 3H, OCH3), 3.88 (s, 3H, OCH3), 68.09 (OC-1), 111.50, 116.06, 127.81, 128.12, 128.30, 131.33, 132.45, 134.32, 136.59, 139.36, 144.21, 150.45; EI-MS (70 eV) m/z (rel. intensity, %) 124 (M+, 15.61), 138 (38.63), 139 (39.57), 147 (42.83), 156 (28.38), 164 (21.35), 172 (18.32), 176 (100). Found: 124 (15.61), 138 (38.63), 139 (39.57), 147 (42.83), 156 (28.38), 164 (21.35), 172 (18.32), 176 (100).

7-Ethoxy-6-methoxyindene (9e)

Pure 9e (0.19 g, 93%) was obtained as colorless liquid; Rf 0.76 (EA/hexane = 1/7); 1H NMR (CDCl3, 400 MHz) δ 3.64 (dd, J = 2.0 Hz, 0.8 Hz, H-1), 3.82 (s, 3H, OCH3), 3.88 (s, 3H, OCH3), 68.09 (OC-1), 111.50, 116.06, 127.81, 128.12, 128.30, 131.33, 132.45, 134.32, 136.59, 139.36, 144.21, 150.45; EI-MS (70 eV) m/z (rel. intensity, %) 124 (M+, 15.61), 138 (38.63), 139 (39.57), 147 (42.83), 156 (28.38), 164 (21.35), 172 (18.32), 176 (100). Found: 124 (15.61), 138 (38.63), 139 (39.57), 147 (42.83), 156 (28.38), 164 (21.35), 172 (18.32), 176 (100).

7-Benzoyloxy-6-methoxyindene (8d)

Pure 8d (0.19 g, 93%) was obtained as colorless liquid; Rf 0.69 (EA/hexane = 1/7); 1H NMR (CDCl3, 500 MHz) δ 3.64 (dd, J = 2.0 Hz, 0.8 Hz, H-1), 3.82 (s, 3H, OCH3), 3.88 (s, 3H, OCH3), 68.09 (OC-1), 111.50, 116.06, 127.81, 128.12, 128.30, 131.33, 132.45, 134.32, 136.59, 139.36, 144.21, 150.45; EI-MS (70 eV) m/z (rel. intensity, %) 124 (M+, 15.61), 138 (38.63), 139 (39.57), 147 (42.83), 156 (28.38), 164 (21.35), 172 (18.32), 176 (100). Found: 124 (15.61), 138 (38.63), 139 (39.57), 147 (42.83), 156 (28.38), 164 (21.35), 172 (18.32), 176 (100).
5.6-Dimethoxyindene (10a)<sup>10b</sup>

Pure 10a (0.16 g, 90%) was obtained as colorless crystals, mp 70-71 °C; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ 1.38 (t, J = 7.0 Hz, 3H, OCH<sub>2</sub>C<sub>6</sub>H<sub>5</sub>), 1.48 (t, J = 2.0 Hz, 0.8 Hz, 1H, H-1), 3.89, 3.90 (each s, 3H, OCH<sub>3</sub>), 6.44 (dd, J = 5.5 Hz, 2.0 Hz, 1H, H-2), 6.79 (dd, J = 5.6 Hz, 0.8 Hz, 1H, H-3), 6.96, 7.07 (each s, 1H, H-7 and H-4); <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ 39.07 (C-1), 56.51 (OC<sub>2</sub>H<sub>5</sub>), 107.66, 108.76, 127.26, 127.67, 128.48, 131.67, 132.74, 136.93, 137.54, 137.65, 147.44, 147.99; EI-MS (70 eV) m/z (rel. intensity, %): 252 (M<sup>+</sup>, 27.00), 161 (100), 133 (41.05), 118 (18.50), 115 (21.92), 105 (56.82), 103 (16.19), 91 (84.57), 90 (25.75), 89 (19.36); HRMS calcd for C<sub>13</sub>H<sub>12</sub>O<sub>2</sub>: 266.1150. Found: 252.1156.

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