Lignans and Triterpenes from the Bark of *Durio carinatus* and *Durio oxleyanus*

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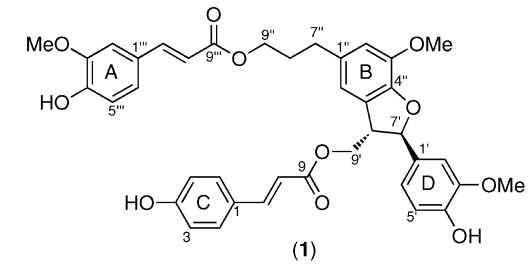
Investigation of chemical constituents from the bark of *Durio carinatus* has led to the isolation of three lignans, boehmenan X (**1**), *threo*-carolignan X (**2**), and *erythro*-carolignan X (**3**), together with the three known lignans boehmenan, *threo*-carolignan E, and *erythro*-carolignan E. The bark of *D. oxleyanus* yielded two new lignan ethers, *threo*-carolignan Y (**4**) and *erythro*-carolignan Y (**5**), together with compounds **1**, **3**, and boehmenan. *J*-Based configurational analysis and NOE measurements were used to explore conformational issues for the lignan diastereomers, while CD measurements supported an 8′*S* configuration for the various lignans. The triterpenes 3β-*O*-*cis*-caffeoylbetulinic acid and 3β-*O*-*trans*-caffeoylbetulinic acid were also characterized from *D. carinatus*.

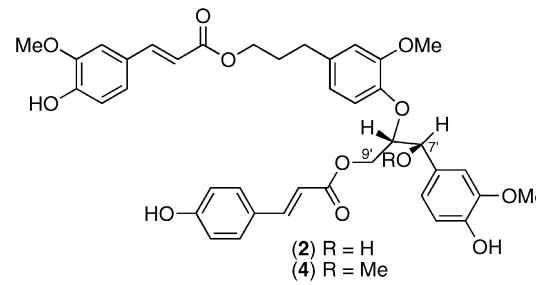
The genus *Durio* belongs to the Bombacaceae family and consists of about 28 species that are widely distributed and which have been cultivated for centuries owing to their economic importance, both as a timber and as a food source. The fruits of the durian tree are considered the "King of Fruits" in many parts of Southeast Asia.[1] Previously we reported the isolation of triterpenes, lignans, and phenolic compounds from two *Durio* species (*D. zibethinus* Murr. and *D. kutejensis* (Hassk.) Becc) collected in West Kalimantan, Borneo.[2] As part of an ongoing study on species from the Bombacaceae, we report herein phytochemical investigations on *D. carinatus* Mast. and *D. oxleyanus* Griff. The fruits of *D. carinatus* are nonedible, while the other three species all have edible fruits.

Results and Discussion

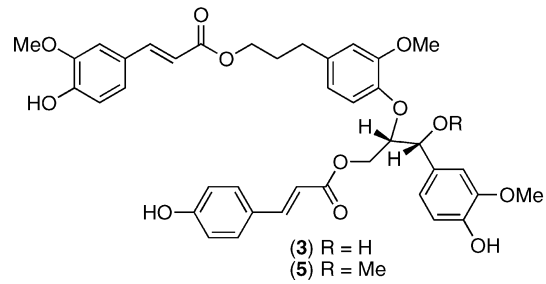
The MeOH-soluble extract of the bark of *D. carinatus* was triturated with hexanes to remove lipids. The methanol-soluble components were then fractionated by vacuum liquid chromatography followed by flash column chromatography and C_{18}-HPLC. Three lignans, (+)-boehmenan X (**1**), (−)-(7′*S*,8′*S*)-*threo*-carolignan X (**2**), and (−)-(7′*R*,8′*S*)-*erythro*-carolignan X (**3**), were obtained together with the three known lignans, boehmenan, *threo*-carolignan E, and *erythro*-carolignan E.[3,4] In the same way, fractionation of the $CHCl_3$-soluble components of a MeOH extract of the bark of *D. oxleyanus* provided five lignans, comprising (−)-(7′*S*,8′*S*)-*threo*-carolignan Y (**4**) and (−)-(7′*R*,8′*S*)-*erythro*-carolignan Y (**5**) together with compounds **1**, **3**, and boehmenan. In addition, the known triterpenes 3β-*O*-*cis*-caffeoylbetulinic acid and the known 3β-*O*-*trans*-caffeoylbetulinic acid were obtained from *D. carinatus*.[5−9] The structures and stereochemistry of these compounds were solved by MS and NMR methods including NOESY and HSQC-HECADE and by interpretation of CD data.



(**1**)



(**2**) R = H
(**4**) R = Me



(**3**) R = H
(**5**) R = Me

Compound **1** was isolated as a white, amorphous solid. The positive-ion HRESIMS of **1** gave a pseudomolecular $[M + Na]^+$ ion at *m/z* 705.2298, corresponding to the molecular formula $C_{39}H_{38}O_{11}$. The ^{1}H NMR spectrum (Table 1) revealed two sets of signals for aromatic and olefinic protons that were fully consistent with the presence of both feruloyloxy (ring A; δ 7.13 (1H, d, J = 1.8 Hz, H-2‴), 6.78 (1H, d, J = 8.1 Hz, H-5‴), 7.03 (1H, dd, J = 1.8, 8.1 Hz, H-6‴), 7.49 (1H, d, J = 15.9 Hz, H-7‴), and 6.26 (1H, d, J = 15.9 Hz, H-8‴)) and *p*-coumaroyloxy (ring C; δ 7.36 (2H, d, J = 8.5 Hz, H-2 and H-6), 6.75 (2H, d, J = 8.5 Hz, H-3 and H-5), 7.43 (1H, d, J = 15.9 Hz, H-7), and 6.21 (1H, d, J = 15.9 Hz, H-8)) units. Adjacent methine signals at δ 5.38 (1H, d, J = 7.4 Hz, H-7′) and δ 3.78 (1H, m, H-8′), together with proton signals at δ 6.77 (1H, br s, H-2″) and 6.74 (1H, br s, H-6″), and an *O*-methyl resonance at δ 3.84 (OCH_3-3″) were supportive of the tetrasubstituted dihydrobenzofuran (ring B). There were also resonances for oxymethylene protons at δ 4.52 (1H, dd, J = 5.1, 11.0 Hz, H-9′a) and 4.36 (1H, dd, J = 7.9, 11.0 Hz, H-9′b) and for three contiguous methylene groups at δ 2.70 (2H, t, J = 7.3 Hz, H-7″), 2.00 (2H, m, H-8″), and 4.17 (2H, m, H-9″). These data, together with signals corresponding to an additional 1,3,4-trisubstituted aromatic unit (ring D), closely matched those of the co-

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Table 1. ^{1}H NMR Assignments for Compounds **1**−**5**[a]

position	**1**[b]	**2**[c]	**3**[c]	**4**[c]	**5**[c]
2	7.36, d (8.5)	7.38, d (8.6)	7.35, d (8.6)	7.34, d (8.6)	7.34, d (8.6)
3	6.75, d (8.5)	6.82, d (8.6)	6.80, d (8.6)	6.81, d (8.6)	6.80, d (8.6)
5	6.75, d (8.5)	6.82, d (8.6)	6.80, d (8.6)	6.81, d (8.6)	6.80, d (8.6)
6	7.36, d (8.5)	7.38, d (8.6)	7.35, d (8.6)	7.34, d (8.6)	7.34, d (8.6)
7	7.43, d (15.9)	7.51, d (15.8)	7.48, d (15.9)	7.43, d (15.9)	7.44, d (15.9)
8	6.21, d (15.9)	6.24, d (15.8)	6.19, d (15.9)	6.18, d (15.9)	6.21, d (15.9)
2′	6.92, d (1.8)	6.89, br s	7.01, m	6.94, br s	6.91, d (1.5)
5′	6.76, d (8.2)	6.85, d (8.2)	6.85, d (8.1)	6.86, m	6.86, m
6′	6.82, dd (1.8, 8.2)	6.87, dd (1.7, 8.2)	6.81, m	6.86, m	6.87, m
7′	5.38, d (7.4)	4.89, d (8.2)	4.90, d (2.6)	4.46, d (5.8)	4.42, d (6.1)
8′	3.78, m	4.21, m	4.46, m	4.49, m	4.47, m
9′	4.52, dd (5.1, 11.0)	4.32, dd (3.4, 12.1)	4.45, dd (7.2, 15.0)	4.31, dd (3.8, 11.7)	4.51, m
	4.36, dd (7.9, 11.0)	4.11, dd (5.1, 12.1)	4.25, dd (6.7, 15.0)	4.13, dd (6.0, 11.7)	
2″	6.77, br s	6.75, br s	6.74, d (1.9)	6.67, m	6.61, d (1.8)
5″		7.07, d (8.0)	6.95, d (8.0)	6.91, d (7.7)	6.63, d (8.0)
6″	6.74, br s	6.73, dd (1.7, 8.0)	6.73, dd (1.9, 8.0)	6.67, m	6.59, dd (1.8, 8.0)
7″	2.70, t (7.3)	2.68, t (7.1)	2.67, t (7.4)	2.63, m	2.60, m
8″	2.00, m	1.99, t (7.9)	1.99, m	1.96, m	1.93, m
9″	4.17, m	4.20, t (6.7)	4.20, t (6.5)	4.18, t (6.5)	4.16, t (6.6)
2‴	7.13, d (1.8)	7.02, d, (1.7)	7.01, m	7.01, d (1.6)	7.01, d (1.7)
5‴	6.78, d (8.1)	6.91, d (8.1)	6.90, d (8.2)	6.90, d (8.1)	6.90, d (8.2)
6‴	7.03, dd (1.8, 8.1)	7.06, dd (1.7, 8.1)	7.06, dd (1.7, 8.2)	7.06, dd (1.6, 8.1)	7.05, dd (1.7, 8.2)
7‴	7.49, d (15.9)	7.59, d (15.8)	7.59, d (15.9)	7.59, d (15.9)	7.59, d (15.9)
8‴	6.26, d (15.9)	6.28, d (15.8)	6.28, d (15.9)	6.28, d (15.9)	6.28, d (15.9)
OMe-3′	3.76, s	3.84, s	3.85, s	3.83, s	3.82, s
OMe-3″	3.84, s	3.87, s	3.84, s	3.76, s	3.71, s
OMe-3‴	3.86, s	3.92, s	3.90, s	3.91, s	3.90, s
OMe-7′				3.30, s	3.27, s

[a] At 750 MHz. [b] In MeOH-d_4; chemical shifts referenced to MeOH at δ_H 3.30. [c] In $CDCl_3$; chemical shifts referenced to $CHCl_3$ at δ_H 7.24.

metabolite boehmenan, except for the replacement of one of the two feruloyloxy units of boehmenan by a *p*-coumaroyloxy unit in **1**. The points of attachment of the two C_6C_3 units, and the assignment of the C-9 and C-9‴ resonances (see Table 2), were secured by HMBC correlations from the methylene protons at δ 4.17 (H-9″) and the olefinic protons at δ 7.49 (H-7‴) and 6.26 (H-8‴) to the feruloyloxy carbonyl (C-9‴) at δ 169.4 and from the geminal protons at δ 4.52 (H-9′a) and 4.36 (H-9′b) and the olefinic protons at δ 7.43 (H-7) and 6.21 (H-8) to the *p*-coumaroyloxy carbonyl (C-9) at δ 168.9. Compound **1** is thus closely related to the known lignan boehmenan K,[4] except for the absence of a double bond between C-7″ and C-8″ and the position of the C_6C_3 substituents. In the structure assigned to boehmenan K, the feruloyloxy and *p*-coumaroyloxy units were attached at C-9′ and C-9″, respectively, on the basis of HMBC correlations; however the ^{13}C NMR values cited for the two carbonyls (C-9 and C-9‴) were only 0.1 ppm or 7.5 Hz (recorded at 75.47 MHz) apart.[4] In contrast, for compound **1**, the ^{13}C NMR values for the carbonyls are 0.5 ppm or 94 Hz (recorded at 188.45 MHz) apart.

In a report on the lignan chemistry of *Corylus sieboldiana* Blume, Watanabe et al. reported the isolation of a dihydrobenzofuran lignan structurally similar to **1**, but with characterization limited to ^{1}H NMR data for a triacetate derivative. These authors did not specify the locations of the *p*-coumaroyloxy and feruloyloxy substituents, nor did they determine the relative configuration of the metabolite.[10] The relative configuration of **1**, named boehmenan X, was confirmed by the 7.4 Hz coupling between H-7′ and H-8′, indicating that these two protons have a *trans* configuration. Compound **1** has a specific rotation $[\alpha]^{28}_D$ +11.2 (*c* 0.41, $CHCl_3$), which is opposite in sign to boehmenan isolated from *Helicteres hirsuta* ($[\alpha]_D$ −14.3 (*c* 0.03, $CHCl_3$)).[11] There is no $[\alpha]_D$ value reported for boehmenan K,[4] while a value of +2.3 (*c* 0.50, MeOH) was reported for the *C. sieboldiana* metabolite.[10]

Compounds **2** and **3** were both obtained as white, amorphous solids whose molecular formulas were deduced as $C_{39}H_{40}O_{12}$ from HRESIMS data. The ^{1}H NMR data ($CDCl_3$) of **2** showed several resonances that were similar to those in **1**, but there was an additional proton signal at δ 7.07 (1H, d, J = 8.0 Hz, H-5″), which belonged to a 1,3,4-trisubstituted aromatic (ring B). Furthermore,

Table 2. ^{13}C NMR Assignments for Compounds **1**−**5**[a]

position	**1**[b]	**2**[c]	**3**[c]	**4**[c]	**5**[c]
1	126.5, C	127.2, C	127.1, C	127.2, C	127.2, C
2	131.3, CH	130.0, CH	130.0, CH	129.9, CH	129.9, CH
3	117.2, CH	115.8, CH	115.9, CH	115.9, CH	115.8, CH
4	162.3, C	157.8, C	157.8, C	157.6, C	157.6, C
5	117.2, CH	115.8, CH	115.9, CH	115.9, CH	115.8, CH
6	131.3, CH	130.0, CH	130.0, CH	129.9, CH	129.9, CH
7	147.2, CH	145.0, CH	144.8, CH	144.5, CH	144.4, CH
8	114.2, CH	114.8, CH	115.0, CH	115.2, CH	115.4, CH
9	168.9, C	166.7, C	167.2, C	166.8, C	167.1, C
1′	133.7, C	131.1, C	131.0, C	129.8, C	130.1, C
2′	110.9, CH	109.3, CH	108.8, CH	109.7, CH	109.9, CH
3′	149.1, C	146.7, C	146.6, C	146.7, C	146.5, C
4′	147.8, C	145.7, C	145.1, C	145.6, C	145.4, C
5′	116.2, CH	114.4, CH	114.1, CH	114.1, CH	114.0, CH
6′	120.2, CH	120.4, CH	119.3, CH	120.8, CH	121.0, CH
7′	90.1, CH	74.4, CH	72.2, CH	83.3, CH	82.6, CH
8′	51.9, CH	86.2, CH	84.5, CH	82.2, CH	82.5, CH
9′	66.6, CH_2	63.1, CH_2	62.7, CH_2	63.8, CH_2	63.7, CH_2
1″	136.6, C	137.4, C	137.3, C	135.7, C	135.9, C
2″	114.4, CH	112.2, CH	112.4, CH	112.4, CH	112.5, CH
3″	145.4, C	150.7, C	151.3, C	150.7, C	150.7, C
4″	147.6, C	146.1, C	145.2, C	146.6, C	146.1, C
5″	129.0, C	120.6, CH	120.7, CH	118.4, CH	118.9, CH
6″	117.7, CH	121.0, CH	121.1, CH	120.4, CH	120.4, CH
7″	33.3, CH_2	31.9, CH_2	32.0, CH_2	31.8, CH_2	31.8, CH_2
8″	31.7, CH_2	30.4, CH_2	30.4, CH_2	30.4, CH_2	30.3, CH_2
9″	64.9, CH_2	63.7, CH_2	63.7, CH_2	63.9, CH_2	63.8, CH_2
1‴	127.2, C	126.8, C	126.9, C	126.9, C	126.9, C
2‴	111.7, CH	109.4, CH	109.4, CH	109.4, CH	109.4, CH
3‴	149.6, C	146.8, C	146.8, C	146.8, C	146.8, C
4‴	151.5, C	148.0, C	148.0, C	148.0, C	148.0, C
5‴	116.7, CH	114.7, CH	114.7, CH	114.7, CH	114.7, CH
6‴	124.2, CH	123.0, CH	123.1, CH	123.0, CH	123.0, CH
7‴	146.8, CH	145.1, CH	145.0, CH	144.9, CH	144.9, CH
8‴	115.1, CH	115.3, CH	115.3, CH	115.4, CH	115.4, CH
9‴	169.4, C	167.2, C	167.4, C	167.3, C	167.4, C
OMe-3′	56.4, CH_3	55.8, CH_3	55.9, CH_3	55.9, CH_3	55.9, CH_3
OMe-3″	56.7, CH_3	55.8, CH_3	55.9, CH_3	55.8, CH_3	55.7, CH_3
OMe-3‴	56.7, CH_3	55.8, CH_3	55.9, CH_3	55.9, CH_3	55.9, CH_3
OMe-7′				57.2, CH_3	57.1, CH_3

[a] At 188.45 MHz. [b] In MeOH-d_4; chemical shifts referenced to MeOH at δ_C 49.0. [c] In $CDCl_3$; chemical shifts referenced to $CHCl_3$ at δ_C 77.0.

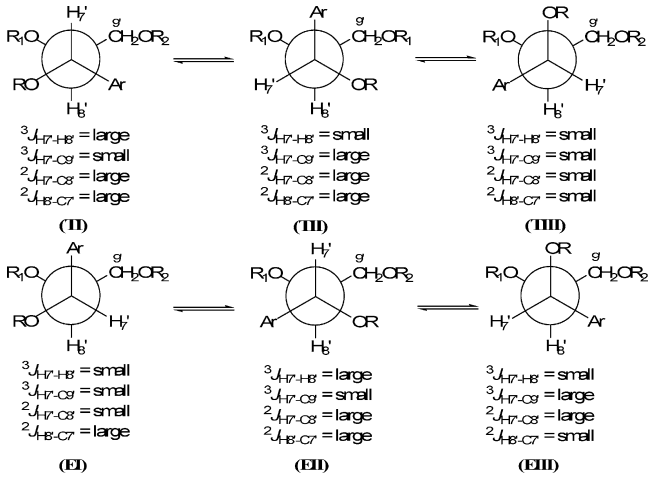

Figure 1. Relative configuration assignment for the C-7′/C-8′ segment of diastereomeric carolignans **2**−**5**: (top) three possible staggered conformers for **2** (R = H) or for **4** (R = Me); (bottom) three possible staggered conformers for **3** (R = H) or for **5** (R = Me). R_1 and R_2 represent the *trans*-feruloyl and *p*-coumaroyl fragments, respectively.

there were 1,2,3-trioxygenated propanoid signals at δ 4.89 (1H, d, J = 8.2 Hz, H-7′), 4.21 (1H, m, H-8′), 4.32 (1H, dd, J = 3.4, 12.1 Hz, H-9′a), and 4.11 (1H, dd, J = 5.1, 12.1 Hz, H-9′b). The link between the 1,2,3-trioxygenated propanoid moiety and the two aromatic rings B and D was established by long-range HMBC correlations. H-8′ showed HMBC correlations to the quaternary carbons at δ 146.1 and 131.1, assigned to C-4″ in ring B and C-1′ in ring D, respectively. The ^{1}H NMR spectrum ($CDCl_3$) of compound **3** was similar to that of **2** except for the appearance of an oxymethine proton at δ 4.90 (1H, H-7′) as a doublet with J = 2.6 Hz to H-8′ instead of at δ 4.89 with J = 8.2 Hz. In addition, the methine proton at δ 4.46 (1H, m, H-8′) was shifted downfield compared to **2**, in which the signal was at δ 4.21. By comparison of these data with those of *threo*-carolignan E and *erythro*-carolignan E,[3,4] compounds **2** and **3** were deduced as a *threo*/*erythro* pair of carolignan metabolites; the C_6C_3 substitution pattern was identical to that of **1** with the *p*-coumaroyloxy and feruloyloxy units positioned at C-9′ and C-9″ from inspection of HMBC data.

Figure 1 shows the three possible staggered conformers that can be drawn for each of the diastereomers **2** and **3** together with the approximate magnitude of the $^3J_{HH}$ or $^{2,3}J_{HC}$ that would be expected for each conformation.[12,13] According to the configurational model for lignan diastereomers proposed by Braga et al.,[14] the *threo* isomer **2** adopts conformation **TI** owing to intramolecular hydrogen bonding between the 7′-OH and the aryloxy oxygen of ring B, and thus H-7′ and H-8′ are *anti*. The same hydrogen-bonding effect requires the *erythro* isomer **3** to adopt the conformation **EI**, in which H-7′ and H-8′ are *gauche*, leading to a smaller $^3J_{H7'-H8'}$ for this diastereomer. A second conformer, **EIII**, in which these two hydrogens are again *gauche*, also contributes to the overall conformational equilibrium for the *erythro* diastereomer. On the basis of the J values of **2** and **3** indicated earlier, it was apparent that **2** and **3** were the *threo* and *erythro* isomers, respectively. Comparison of the ^{13}C NMR data reveals downfield shifts for C-7, C-8, and C-9 of the *threo* isomer compared to the *erythro* form, a trend previously noted by Braga et al.[14] and by Wu et al.[15]

In view of the medium-sized $^3J_{H7'-H8'}$ of 8.2 Hz for **2**, we considered it possible that conformer **TIII**, showing intramolecular hydrogen bonding but with H-7 and H-8 in a *gauche* relationship, might also contribute to the overall conformational equilibrium for **2**. Likewise, conformer **EII**, in which the bulky substituents are separated and dipole effects are minimized, was also a plausible conformer for **3**. To gain additional insight into the conformational preferences, $^{2,3}J_{HC}$ values, which are valuable in determining conformational equilibria,[13] were measured for each diastereomer using the HSQC-HECADE (heteronuclear couplings from ASSCI-domain experiments with E.COSY-type crosspeaks) method.[16,17] The *threo* isomer **2** showed a small $^3J_{H7'-C9'}$ of +0.2 Hz and medium to large ^2J values ($^2J_{H7'-C8'}$ of −3.5 Hz and $^2J_{H8'-C7'}$ of −4.6 Hz), in agreement with **TI** as the dominant conformer, but also suggesting a contribution from conformer **TIII**. For *erythro* **3**, a $^3J_{H7'-C9'}$ of +2.8 Hz was measured, considered small, while $^2J_{H7'-C8'}$ and $^2J_{H8'-C7'}$ were measured as −2.5 and −0.6 Hz and described as medium and small, respectively.[12,13] These data matched a conformational equilibrium involving **EI** and **EIII** as the major contributors. Overall, hydrogen-bonding effects rather than steric effects dominated the conformational preferences despite the presence of bulky C_6C_3 side chains.

Other features of the proton spectra ($CDCl_3$) of compounds **2** and **3** supported the conformational model. In **2**, the presence of NOESY correlations between H-7′/H-5″, H-2′/H-8′, and H-6′/H-8′ fit the **TI** conformation, while a correlation between H-7′/H-8′ agreed with a contribution from the minor conformer **TIII**. In **3**, correlations between H-2′/H-5″ and H-7′/H-8′ were consistent with conformer **EI**, while correlations between H-2′/H-8′ and H-6′/H-8′ supported contributions from conformer **EIII** and/or from **EII**. Figure 2 shows 3D models of conformers **TI** and **EI**, with key NOE interactions identified.

Lignan ethers **4** and **5** were isolated from the $CHCl_3$-soluble extract of *D. oxleyanus*. Each showed LRMS pseudomolecular ions 14 mass units higher than for **2** or **3** and gave HRESIMS data consistent with a molecular formula of $C_{40}H_{42}O_{12}$. Their ^{1}H and ^{13}C NMR spectra ($CDCl_3$) were closely similar to those of **2** and **3**, respectively, but contained an extra *O*-methyl signal (^{1}H: δ 3.30 in **4** and δ 3.27 in **5**). The H-7′ signals at δ 4.46 and 4.42, respectively, now appeared upfield compared to those in **2** and **3**, consistent with the replacement of 7′-OH by 7′-OMe. The $^3J_{H7'-H8'}$ values for **4** and **5** were 5.8 and 6.1 Hz, respectively; because of the close similarity of these values, the relative configurations of **4** and **5** could not be determined. In HSQC-HECADE experiments, isomer **4** showed a small $^3J_{H7'-C9'}$ of +1.0 Hz and large values for $^2J_{H8'-C7'}$ (−3.9 Hz) and $^2J_{H7'-C8'}$ (−4.5 Hz), while the corresponding values for **5** measured as $^3J_{H7'-C9'}$ +2.4 Hz, $^2J_{H8'-C7'}$ −3.6 Hz, and $^2J_{H7'-C8'}$ −5.3 Hz were considered small, large, and large, respectively. Likewise these data did not permit assignment of relative configuration. However in **4**, an NOE was observed between the 7′-OMe and H-5″ and between H-2′ and H-9′, while in **5** there were NOEs between the 7′-OMe and H-9′. Thus, **4** and **5** were suggested as *threo* and *erythro*, respectively. Moreover, the increased value of $^3J_{H7'-H8'}$ for **5** compared to **3** supported a modified conformational model in which conformer **EII** predominated due to loss of the hydrogen-bonding interactions.

Additional confirmation of the assigned relative configuration was provided by consideration of ^{1}H NMR data for **2**−**5** in MeOH-d_4. For **2** and **3** in this solvent, the intramolecular hydrogen bonding between the 7′-OH and the ring B-aryloxy oxygen is replaced by hydrogen bonding of the 7′-OH to the solvent. Consequently, conformational preferences are dictated by steric effects alone. Whereas *threo* **2** retains **TI** as the major conformer, the predominant conformer for *erythro* **3** changes to **EII** (rather than the **EI**/**EIII** observed in $CHCl_3$). This solvent-dependent conformational picture was apparent in ^{1}H NMR spectra of **3**. The $^3J_{H7'-H8'}$ value of 2.6 Hz ($CDCl_3$) changed to 6.1 Hz in MeOH-d_4, this latter value matching that of **5** in either $CDCl_3$ (6.1 Hz) or MeOH-d_4 (6.0 Hz); for comparison, $^3J_{H7'-H8'}$ for **2** was 6.0 Hz in MeOH-d_4 compared to 8.2 Hz in $CDCl_3$, and that of **4** was 6.0 Hz (MeOH-d_4) or 5.8 Hz ($CDCl_3$). In MeOH-d_4, the geminal H-9′ protons of *threo* compounds **2** and **4** appeared as a distinctive doublet of doublets, a consequence of their proximity to the shielding cone of the aromatic ring D, as did the H-9′ protons of the co-metabolite *threo*-carolignan E. In contrast, in *erythro* **3** and **5** and in *erythro*-

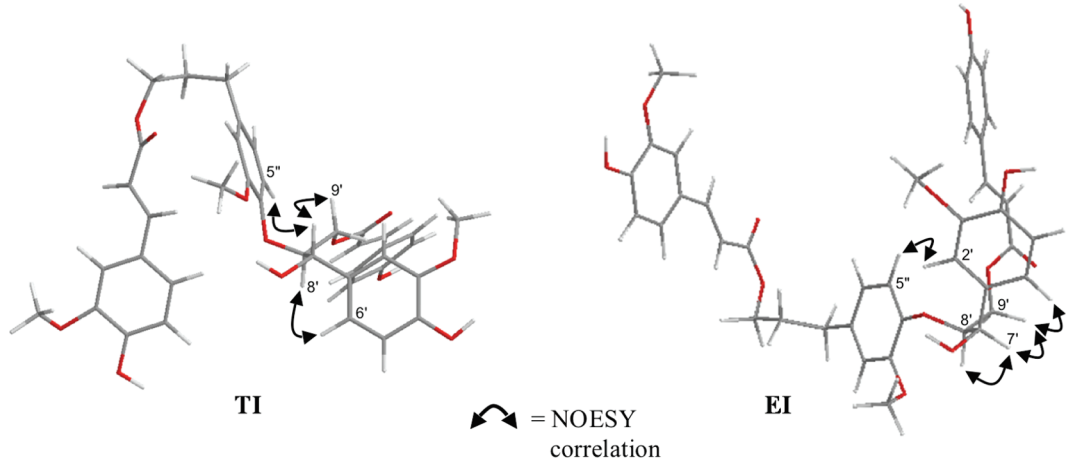

Figure 2. 3D models of conformers **TI** (for compound **2**) and **EI** (for compound **3**) together with some selected NOESY correlations shown by compounds **2** and **3** in $CDCl_3$.

carolignan E, the H-9′ signals presented as a complex, two-proton multiplet (see Supporting Information for ^{1}H NMR comparisons).

The absolute configurations of lignans **2**−**5** were each investigated by CD spectroscopy and compared with literature data. The chiral synthetic product (+)-(1*R*,2*S*)-2-(2-hydroxyphenoxy)-1-phenylpropan-1-ol prepared by Arnoldi et al. shows a positive Cotton effect at 230 nm.[18] By comparison with this data, two (−)-*threo* lignan glycosides obtained from *Arum italicum* were assigned a 7′*S*,8′*S* configuration when they showed positive Cotton effects at 239 and 240 nm, respectively.[19,20] A series of four stereoisomers with a neolignan framework were isolated by Huo et al. from *Symplocos caudata*, and each was assigned either an 8′*S* or 8′*R* configuration based on a positive or negative Cotton effect in the region 235−240 nm.[21] Also, (−)-*threo*-demethylcarolignan E, isolated by Wu et al.[15] from the stems of *Hibiscus taiwanensis*, showed a positive Cotton effect at 234 nm, determined as a 7′*S*,8′*S* configuration. These lignans all show a trend in which the Cotton effect in the 230−240 nm range is positive when the C-8′ configuration is *S*. It was also apparent from the published CD data on lignans that the *erythro* isomer shows a red-shifted maximum compared to its *threo* counterpart.[15,18−22]

For ease of comparison, the CD spectra of **2**−**5** were measured in acetonitrile rather than in $CHCl_3$; in this solvent, the major conformers were revealed as **TI** (for **2** and **4**) and **EII** (for **3** and **5**) by ^{1}H NMR study. Lignans **2** and **3** showed positive Cotton effects at 236.8 and 238.6 nm, respectively. The spectrum of *erythro* **3** was red-shifted in comparison with that of *threo* **2**. For the lignan ethers, *threo* **4** showed a positive Cotton effect at 238.8 nm, while *erythro* **5** gave a positive Cotton effect at 240 nm, again red-shifted compared to the *threo* isomer. These data supported a 7′*S*,8′*S* configuration for the *threo* isomers **2** and **4** and a 7′*R*,8′*S* configuration for *erythro* **3** and **5**. However this interpretation should be regarded as provisional until the experimental data for **2**−**5** can be compared to their theoretically calculated CD spectra. This study will be essential because CD spectra are well known to be sensitive to conformational issues.[23,24]

The $[\alpha]^{22}_D$ values measured for isomers **2** and **3** in MeOH were −14.4 (*c* 0.1, MeOH) and −6.8 (*c* 0.25, MeOH), respectively. In contrast, in $CHCl_3$, **2** showed an $[\alpha]^{22}_D$ value of −6.3 (*c* 0.1), and an $[\alpha]^{22}_D$ value of +20.6 (*c* 2.5) was measured for **3**. The solvent dependency apparent in the $[\alpha]_D$ data of *erythro* **3** was linked to the conformational model. As indicated earlier, in MeOH, the predominant conformer for *erythro* **3** changes to **EII** (rather than the **EI**/**EIII** observed in $CHCl_3$), whereas the *threo* **2** retains **TI** as the predominant conformer. The $[\alpha]_D$ values of the two *O*-methyl compounds **4** and **5** were −16.0 (*c* 0.2, MeOH) and −2.6 (*c* 0.2, MeOH), respectively. When these values were compared to data for **2** and **3** and for the co-metabolite pair *threo*/*erythro*-carolignan E, some trends were apparent. The $[\alpha]_D$ values of the *threo* compounds **2** and **4** and of *threo*-carolignan E ($[\alpha]_D$ −4.2) were all more negative than their *erythro* counterparts, **3**, **5**, and *erythro*-carolignan E ($[\alpha]_D$ −3.1).

Given that C-7′ is a benzylic center, it may be that **4** and **5** are products of the isolation procedure since the extraction involved the use of MeOH. However the *O*-methyl compounds were not isolated from *D. carinatus* even though all extracts were prepared using similar extraction conditions.

Five known compounds were also isolated and identified as boehmenan, *threo*-carolignan E, *erythro*-carolignan E,[3,4] 3*β*-*O*-*trans*-caffeoylbetulinic acid,[5−9] and 3*β*-*O*-*cis*-caffeoylbetulinic acid.[7,8] The absolute configuration of the *threo*/*erythro*-carolignan E pair was provisionally assigned for the first time as 7′*S*,8′*S* and 7′*R*,8′*S*, respectively, from CD data. In conclusion, in this study six lignans and two triterpenes were isolated from the bark of nonedible fruit bearing *D. carinatus* Mast, while *D. oxleyanus* Griff. provided a diastereomeric pair of lignan ethers in addition to three other lignans. The exploration of chemical constituents from other *Durio* species will lead to confirmation of the diagnostic chemistry of *Durio*.

Experimental Section

General Experimental Procedures. Optical rotations ($[\alpha]_D$) and CD spectra were measured on a Perkin-Elmer 241 MC polarimeter and on a Jasco-J810 spectropolarimeter, respectively. HRESIMS were measured using a Finnigan MAT 900 XL double focusing magnetic sector mass spectrometer in the positive-ion mode. The ^{1}H, ^{13}C, HSQC, HMBC, DQF-COSY, NOESY, and HSQC-HECADE spectra were recorded on either Bruker Avance 400, Bruker Avance 500, or Bruker Avance 750 MHz spectrometers. ^{1}H NMR spectra were recorded relative to $CDCl_3$ (δ = 7.24 ppm) and MeOH-d_4 (δ = 3.30 ppm), whereas ^{13}C NMR spectra were recorded relative to either $CDCl_3$ (δ = 77.0 ppm) or MeOH-d_4 (δ = 49.0 ppm). VLC was carried out on silica gel (Kieselgel 60 H), and flash column chromatography was carried out on silica gel 60 (230−400 mesh). TLC analysis was performed on precoated silica gel plates (Kieselgel 60 F_{254} or RP-18 F_{254s}, 20 × 20 cm, 0.25 mm thick, Merck). Spots were detected under UV light at λ_{254} and λ_{366} nm or by using ceric sulfate spray reagent. C_{18}-HPLC was performed on an Agilent 1100 series instrument with a variable-wavelength UV detector set at 254 nm. Semipreparative separation used a μBondapak C_{18} (7.8 × 300 mm) 10 μm column (Waters). All solvents used were distilled prior to use.

Plant Material. Bark samples of *Durio carinatus* Mast. and *Durio oxleyanus* Becc. were collected in Hutan Tapar Hantu (Sambas district, Pontianak, West Kalimantan) in January 2003 and in the Bengkayang region of West Kalimantan in November 2006, respectively. Each sample was air-dried, then powdered. The plants were identified by

the staff of the Bogoriense Herbarium in Bogor, where the voucher specimens are stored. Voucher specimen numbers are 018/IPH.1.02/If.8/2003 for *D. carinatus* and 864/IPH.1.02/If.8/2007 for *D. oxleyanus*.

Extraction and Isolation. Powdered stem bark (1.5 kg) of *D. carinatus* was exhaustively macerated with MeOH (3 × 7 L) for 24 h. The MeOH extract, on removal of solvent under reduced pressure, gave a dark brown residue (15 g, 1%). This was solubilized in a mixture of MeOH−H_2O (9:1) and partitioned with hexanes (3 × 1.5 L). The MeOH-soluble extract (12.9 g) was fractionated by VLC using hexanes, $CHCl_3$, EtOAc, and MeOH (each collection was 250 mL) in increasing polarity. Fifteen fractions (DC1−DC15) were obtained by combining the eluates on the basis of TLC analyses. Fraction DC2 (1676 mg) was further purified by VLC using hexanes, $CHCl_3$, and MeOH (each collection was 100 mL) in order of increasing polarity to obtain 10 fractions (DC2a−DC2j). Fraction DC2j was subjected to Si gel flash CC using a gradient of $CHCl_3$−MeOH (10:0 to 8:2) in order of increasing polarity to yield eight fractions (DC2j1 to DC2j8). Fraction DC2j3 was purified by flash CC and C_{18}-HPLC [MeCN−H_2O (6:4) over 40 min, flow rate 1.5 mL/min, UV detection at 254 nm] to give **1** (4.1 mg). The combined DC2j5 and DC2j6 fractions were also subjected to flash CC, then purified by C_{18}-HPLC [MeCN−H_2O (3:1) over 45 min, flow rate 1.5 mL/min, UV detection at 254 nm] to obtain 3*β*-*O*-*cis*-caffeoylbetulinic acid (0.9 mg) and 3*β*-*O*-*trans*-caffeoylbetulinic acid (2.5 mg). Compounds **2** (5 mg) and **3** (6 mg) were isolated from fraction DC5 (875 mg) by repeated flash CC using gradients of hexanes, $CHCl_3$, EtOAc, and MeOH in order of increasing polarity to obtain seven fractions (DC5c1−DC5c7). Fraction DC5c4 was purified by C_{18}-HPLC [MeOH−H_2O (3:1) over 25 min, flow rate 1.5 mL/min, UV detection 254 nm] to obtain **2** (5 mg), while fraction DC5c3 was purified by C_{18}-HPLC [a linear gradient of MeOH−H_2O (6:4 to 7:3) over 35 min, then MeOH−H_2O (7:3) over 15 min, flow rate 1.5 mL/min, UV detection at 254 nm] to obtain **3** (6 mg). Repeated flash CC of the combined fractions DC3 and DC4 on silica gel and further purification by semipreparative C_{18}-HPLC afforded boehmenan (3 mg), *threo*-carolignan E (3 mg), and *erythro*-carolignan E (8 mg), respectively.

Powdered bark (7 kg) of *D. oxleyanus* was macerated with MeOH (3 × 20 L) for 24 h to provide 700 g of residue (10%), which was subsequently dissolved in a mixture of MeOH−H_2O (9:1), then partitioned using hexanes (3 × 3 L), $CHCl_3$ (3 × 5 L), and EtOAc (3 × 5 L), respectively. The $CHCl_3$ extract (20.1 g) was fractionated by NP vacuum chromatography using a gradient of hexanes, $CHCl_3$, and MeOH (each collection was 250 mL) by increasing polarity to give 23 fractions (D1−D23) on the basis of TLC analyses. The combined fractions D7 and D8 (1.23 g) were purified by NP vacuum chromatography using a gradient of hexanes, EtOAc, and MeOH (each collection was 100 mL) in order of increasing polarity to obtain nine fractions (D78A to D78I). Fraction D78G (60 mg) was subjected to Si gel flash CC using a gradient of hexanes, EtOAc, and MeOH (each collection was 20 mL) in order of increasing polarity to yield three fractions (D78GA−D78GC). Fraction D78GA (12 mg) was purified by C_{18}-HPLC [MeOH−H_2O (3:1) over 30 min, flow rate 1.5 mL/min, UV detection at 254 nm] to give **3** (5 mg). Compounds **4** (3 mg) and **5** (5 mg) were also purified from fraction D78GB (10 mg) by C_{18}-HPLC [MeOH−H_2O (3:1) over 45 min, flow rate 1.5 mL/min, UV detection at 254 nm]. Fractions D78D and D78E were combined and subjected to flash CC using hexanes, EtOAc, and MeOH in order of increasing polarity to give six fractions (D78DE1−D78DE6). Fraction D78DE4 was boehmenan (64 mg), while fraction D78DE2 was fractionated by flash CC following purification with C_{18}-HPLC [MeOH−H_2O (3:1) over 45 min, flow rate 1.5 mL/min, UV detection at 254 nm] to obtain boehmenan X **1** (9 mg).

Compound 1: white, amorphous solid; $[\alpha]^{28}_D$ +11.2 (*c* 0.41, $CHCl_3$); ^{1}H and ^{13}C NMR (MeOH-d_4, 750 MHz), see Tables 1 and 2; HRESIMS *m/z* [M + Na]$^+$ 705.2298 (calcd for $C_{39}H_{38}O_{11}Na$, 705.2312).

Compound 2: white, amorphous solid; $[\alpha]^{22}_D$ −14.4 (*c* 0.1, MeOH), $[\alpha]^{22}_D$ −6.3 (*c* 0.1, $CHCl_3$), CD (MeCN): $[\theta]_{236.8}$ +3.60, $[\theta]_{217}$ −1.03; ^{1}H NMR ($CDCl_3$, 750 MHz), see Table 1; ^{1}H NMR (d_4-MeOH, 500 MHz) *δ* 7.57 (1H, d, *J* = 15.9 Hz, H-7‴), 7.38 (1H, d, *J* = 15.9 Hz, H-7), 7.37 (each 1H, d, *J* = 8.7 Hz, H-2 and H-6), 7.18 (1H, d, *J* = 1.9 Hz, H-2‴), 7.06 (1H, dd, *J* = 1.9, 8.2 Hz, H-6‴), 7.05 (1H, d, *J* = 1.9 Hz, H-2″), 6.96 (1H, d, *J* = 8.1 Hz, H-5″), 6.88 (1H, dd, *J* = 1.8, 8.1 Hz, H-6′), 6.83 (1H, d, *J* = 1.8 Hz, H-2′), 6.80 (1H, d, *J* = 8.2 Hz, H-5‴), 6.79 (1H, d, *J* = 8.1 Hz, H-5′), 6.78 (each 1H, d, *J* = 8.7 Hz, H-3 and H-5), 6.72 (1H, d, *J* = 1.9, 8.1 Hz, H-6″), 6.35 (1H, d, *J* = 15.9 Hz, H-8‴), 6.17 (1H, d, *J* = 15.9 Hz, H-8), 4.90 (1H, d, *J* = 6.0 Hz, H-7′), 4.55 (1H, m, H-8′), 4.26 (1H, dd, *J* = 3.5, 12.0 Hz, H-9′a), 4.14 (2H, t, *J* = 6.5 Hz, H-9″), 4.10 (1H, dd, *J* = 5.0, 12.0 Hz, H-9′b), 3.88 (3H, s, OMe, C-3‴), 3.81 (3H, s, OMe, C-3′), 3.80 (3H, s, OMe,C-3″), 2.65 (2H, t, *J* = 7.3 Hz, CH_2-7″), 1.95 (2H, m, CH_2-8″); ^{13}C NMR ($CDCl_3$, 188.45 MHz), see Table 2; HRESIMS *m/z* [M + Na]$^+$ 723.2382 (calcd for $C_{39}H_{40}O_{12}Na$, 723.2418).

Compound 3: white, amorphous solid; $[\alpha]^{22}_D$ −6.8 (*c* 0.25, MeOH), $[\alpha]^{22}_D$ +20.6 (*c* 0.1, $CHCl_3$); CD (MeCN) $[\theta]_{238.6}$ +3.80, $[\theta]_{224.4}$ −1.61; ^{1}H NMR ($CDCl_3$, 750 MHz), see Table 1; ^{1}H NMR (d_4-MeOH, 500 MHz) *δ* 7.55 (1H, d, *J* = 15.9 Hz, H-7‴), 7.37 (1H, d, *J* = 15.9 Hz, H-7), 7.36 (each 1H, d, *J* = 8.7 Hz, H-2 and H-6), 7.16 (1H, d, *J* = 1.9 Hz, H-2‴), 7.06 (1H, m, H-2′), 7.05 (1H, dd, *J* = 1.9, 8.2 Hz, H-6‴), 6.86 (1H, m, H-6′), 6.83 (1H, d, *J* = 8.1 Hz, H-5″), 6.80 (each 1H, m, H-2″ and H-5‴), 6.79 (each 1H, d, *J* = 8.7 Hz, H-3 and H-5), 6.75 (1H, d, *J* = 8.1 Hz, H-5′), 6.67 (1H, d, *J* = 1.9, 8.1 Hz, H-6″), 6.35 (1H, d, *J* = 15.9 Hz, H-8‴), 6.16 (1H, d, *J* = 15.9 Hz, H-8), 4.90 (1H, d, *J* = 6.1 Hz, H-7′), 4.58 (1H, m, H-8′), 4.43 (1H, m, H-9′), 4.13 (2H, t, *J* = 6.5 Hz, H-9″), 3.88 (3H, s, OMe, C-3‴), 3.81 (3H, s, OMe, C-3′), 3.76 (3H, s, OMe,C-3″), 2.65 (2H, t, *J* = 7.3 Hz, CH_2-7″), 1.95 (2H, m, CH_2-8″); ^{13}C NMR ($CDCl_3$, 188.45 MHz), see Table 2; HRESIMS *m/z* [M + Na]$^+$ 723.2423 (calcd for $C_{39}H_{40}O_{12}Na$, 723.2418).

Compound 4: white, amorphous solid; $[\alpha]^{22}_D$ −16.1 (*c* 0.2, MeOH), $[\alpha]^{22}_D$ +32.6 (*c* 0.2, $CHCl_3$); CD (MeCN) $[\theta]_{238.9}$ +4.34, $[\theta]_{224}$ −1.41; ^{1}H NMR ($CDCl_3$, 750 MHz), see Table 1; ^{1}H NMR (d_4-MeOH, 500 MHz) *δ* 7.58 (1H, d, *J* = 15.8 Hz, H-7‴), 7.49 (1H, d, *J* = 15.8 Hz, H-7), 7.35 (each 1H, d, *J* = 8.5 Hz, H-2 and H-6), 7.06 (1H, dd, *J* = 1.6, 8.2 Hz, H-6‴), 7.02 (1H, d, *J* = 1.6 Hz, H-2‴), 6.95 (1H, br s, H-2′), 6.90 (1H, d, *J* = 7.8 Hz, H-5″), 6.88 (1H, d, *J* = 8.2 Hz, H-5‴), 6.87 (1H, m, H-6′), 6.85 (1H, d, *J* = 7.8 Hz, H-5′), 6.82 (each 1H, d, *J* = 8.5 Hz, H-3 and H-5), 6.66 (each 1H, m, H-2″ and H-6″), 6.26 (1H, d, *J* = 15.8 Hz, H-8‴), 6.15 (1H, d, *J* = 15.8 Hz, H-8), 4.58 (1H, m, H-8′), 4.47 (1H, d, *J* = 6.0 Hz, H-7′), 4.20 (1H, dd, *J* = 3.5, 11.8 Hz, H-9′a), 4.14 (2H, t, *J* = 6.5 Hz, H-9″), 4.07 (1H, dd, *J* = 5.8, 11.8 Hz, H-9′b), 3.93 (3H, s, OMe-3‴), 3.85 (3H, s, OMe-3′), 3.79 (3H, s, OMe-3″), 3.28 (3H, s, OMe-7′), 2.66 (2H, m, CH_2-7″), 1.98 (2H, m, CH_2-8″); ^{13}C NMR ($CDCl_3$, 188.45 MHz), see Table 2; HRESIMS *m/z* [M + Na]$^+$ 737.2568 (calcd for $C_{40}H_{42}O_{12}Na$, 737.2574).

Compound 5: white, amorphous solid; $[\alpha]^{22}_D$ −2.6 (*c* 0.2, MeOH), $[\alpha]^{22}_D$ +48.0 (*c* 0.5, $CHCl_3$); CD (MeCN) $[\theta]_{240.0}$ +2.84, $[\theta]_{226.2}$ −2.18; ^{1}H NMR ($CDCl_3$, 750 MHz), see Table 1; ^{1}H NMR (d_4-MeOH, 500 MHz) *δ* 7.58 (1H, d, *J* = 15.8 Hz, H-7‴), 7.42 (1H, d, *J* = 15.8 Hz, H-7), 7.33 (each 1H, d, *J* = 8.5 Hz, H-2 and H-6), 7.06 (1H, dd, *J* = 1.6, 8.2 Hz, H-6‴), 7.03 (1H, d, *J* = 1.6 Hz, H-2‴), 6.95 (1H, br s, H-2′), 6.89 (1H, d, *J* = 8.2 Hz, H-5‴), 6.85 (1H, m, H-6′), 6.83 (1H, m, H-5′), 6.82 (each 1H, d, *J* = 8.5 Hz, H-3 and H-5), 6.62 (1H, d, *J* = 8.1 Hz, H-5″), 6.61 (1H, d, *J* = 1.8 Hz, H-2″), 6.57 (1H, dd, *J* = 1.8, 8.1 Hz, H-6″), 6.27 (1H, d, *J* = 15.8 Hz, H-8‴), 6.20 (1H, d, *J* = 15.8 Hz, H-8), 4.57 (1H, m, H-8′), 4.46 (2H, m, H-9′a/H-9′b), 4.41 (1H, d, *J* = 6.0 Hz, H-7′), 4.12 (2H, t, *J* = 6.7 Hz, H-9″), 3.91 (3H, s, OMe-3‴), 3.82 (3H, s, OMe-3′), 3.73 (3H, s, OMe-3″), 3.29 (3H, s, OMe-7′), 2.61 (2H, m, CH_2-7″), 1.94 (2H, m, CH_2-8″); ^{13}C NMR ($CDCl_3$, 188.45 MHz), see Table 2; HRESIMS *m/z* [M + Na]$^+$ 737.2568 (calcd for $C_{40}H_{42}O_{12}Na$, 737.2574).

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Supporting Information Available: Figures S1−S7. ^{1}H and ^{13}C NMR data for compounds **1**−**5** and spectroscopic data and characterization details for known compounds. This information is available free of charge via the Internet at http://pubs.acs.org.

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