A Two-Step Efficient Chemoenzymatic Synthesis of Flavonoid Glycoside Malonates

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A simple and high-yielding protocol for the malonylation of some flavonoid glycosides is described. The two-step synthesis is based on the regioselective enzymatic introduction of a benzylmalonyl group by catalysis with the lipase from *Candida antarctica*, followed by Pd/C hydrogenolysis of the benzyl moiety.

As a result of improved extraction and purification procedures and because of the sophisticated analytical tools now available, a rapidly increasing number of malonylated flavonoid glycosides, including anthocyanins, has been detected in plants in recent years.[1] These acidic esters are rather unstable, undergoing facile hydrolysis and/or decarboxylation, and for this reason their isolation has been quite difficult. The exact function of these and other flavonoid esters in cell biosynthetic processes is not well known. Probably they act to mediate among different metabolic fates for the glycosides and might have a controlling or regulating effect on the biosynthesis of these compounds. The malonylated glycosides are of particular interest because they are anionic above pH 3, giving the glycosides distinctive solubility properties.[2] Moreover, the malonyl methylene group can be involved in chemical reactions, for example, the reaction with aromatic aldehydes to form the corresponding phenylpropenoate esters.[3]

In previous work,[3] we reported the first synthetic approach to a malonyl glycoside. Isoquercitrin 6″-*O*-malonate (**1**) was prepared in a two-step procedure by introducing first a methyl malonate residue at the primary OH of the glucose moiety of isoquercitrin (**2**) on reaction with 2-chloroethyl methyl malonate under catalysis by the proteolytic enzyme subtilisin. The mixed diester **3** was then subjected to chemoselective hydrolysis of the methoxycarbonyl function to furnish **1**, and this was successful only by using another enzyme, the so called biophine esterase.[4]

Although isoquercitrin 6″-*O*-malonate (**1**) could be obtained, the above preparation was rather complex and low yielding. The mixed diester **3** was isolated in 22% yield after separation from isomeric compounds; the enzymatic hydrolysis was stopped at 45% conversion, and the desired malonate **1** was obtained in pure form only after preparative reversed-phase HPLC, the usual column chromatographic purification resulting in substantial loss of material by decomposition.

We report here a rapid synthesis of some malonylated flavonoid glycosides, which consists of an efficient enzymatic acylation of the glycosides with dibenzyl-malonate, followed by a facile debenzylation with H_2-Pd/C and recovery of final product simply by filtration of catalyst and solvent evaporation. As dibenzyl malonate was not a substrate for subtilisin, we looked for more suitable enzymes and turned out attention to the lipases. In general, these enzymes are not active in highly polar solvents, like pyridine or DMF,[5] in which the flavonoid glycosides are soluble. After some experimentation we found that dibenzyl malonate is a good substrate for the lipase from *Candida antarctica*, even in an Me_2CO solution containing 10% pyridine to dissolve the flavanone glucoside.

Under these conditions, isoquercitrin (**2**) was transformed into the mixed diester isoquercitrin 6″-*O*-benzyl-malonate (**4**) in acceptable yield (74%) and with high regioselectivity.[6] Other isomers occurred only in negligible amounts. The negative FABMS spectrum of **4** gave the $[M - H]^-$ quasimolecular ion at 639 Da with fragments at 549, 505, and 463 Da due to sequential loss of the benzyl moiety, CO_2, and ketene. The presence in the ^{1}H-NMR spectrum of a low-field AB portion of an ABX system at δ 4.02 (dd, J = 11.5, 6.0 Hz) and 4.26 (dd, J = 11.5, 2.0 Hz) ascertained that a benzyl malonate group was attached at the primary alcoholic function of glucose. The benzylic methylene protons were observed as a singlet at δ 5.08, whereas the signal of the malonate methylene was hidden under the other sugar resonances between δ 3.1 and 3.8. In the ^{13}C-NMR spectrum, C-6″ appeared at δ 64.02 and the two C=O and methylene carbons of the benzyl malonate moiety resonated at δ 166.03 (2) and 40.88 and 66.12, respectively. Catalytic hydrogenation of **4** on Pd/C in THF solution afforded pure **1** in quantitative yield after catalyst filtration and solvent evaporation at room temperature, without need of further purification. Compound **1** was identical in all respects to that previously obtained.[3]

In a similar way, the more complex flavonoid disaccharide monoglycoside rutin (**5**) was transformed into rutin 3″-(*O*-benzyl malonate) (**6**) in 79% yield. The negative FABMS spectrum suggested that acylation occurred at the glucose moiety because the $M - H^-$ ion at 785 Da was accompanied by fragments at 639, 549, and 505 Da due to the sequential loss of an unsubsti-

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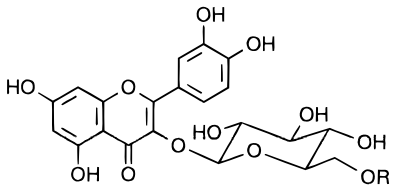
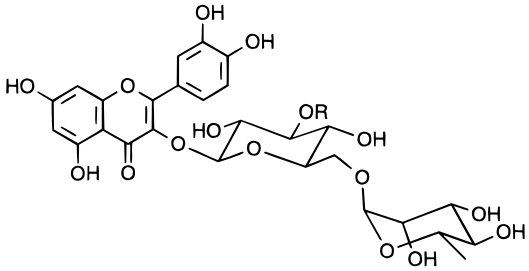


1 : R = $COCH_2COOH$
2 : R = H
3 : R = $COCH_2COOCH_3$
4 : R = $COCH_2COOCH_2C_6H_5$

tuted rhamnose unit, a benzyl moiety, CO_2, and ketene in the gas phase (B/E linked scan experiments). The ^{1}H-NMR spectrum showed a downfield triplet at δ 4.72 (J = 7.5 Hz), which was linked to the signal of the anomeric glucose proton at δ 5.42 (d, J = 7.5 Hz) through a triplet at δ 3.42 due to H-2″ (double resonance experiment), thus indicating that benzylmalonation occurred at the C-3″. On catalytic hydrogenation, **6** gave rutin 3″-*O*-malonate (**7**), $(M - H)^-$ at 695 Da, fragments at 651 and 609, whose NMR spectra were different from those of **6** only in the absence of the benzyl group signals.

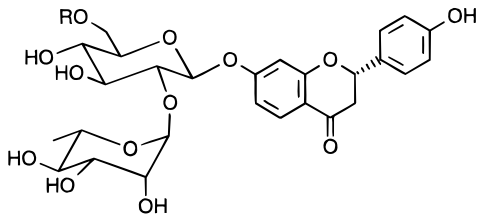


5 : R = H
6 : R = $COCH_2COOCH_2C_6H_5$
7 : R = $COCH_2COOH$

As a third example, this chemical−enzymatic methodology was applied to obtain the 6″-(*O*-malonic acid) ester derivative (**8**)[8] of the bitter flavanone glycoside naringin (**9**). This malonate is abundant in the young leaves and fruits of a grapefruit plant [*Citrus paradisi* (L) MacFad] while the flavanone is being actively synthesized, but it is absent in the mature leaves and fruits when biosynthesis is no longer active. This ester may take part in the translocation process of naringin from a metabolically active pool where it is synthesized, to an inactive pool (the vacuoles). After deposition, the malonyl group is removed, and the malonate is no longer found in the mature fruit.

Malonylation of naringin (**9**) afforded naringin 6″-(*O*-benzyl malonate) (**10**) in 69% yield. Structurally diagnostic signals in the ^{1}H-NMR spectrum of **10** were at δ 4.08 (dd, J = 11.5, 7.0 Hz) and δ 4.32 (broad d, J = 11.5 Hz) for the diastereotopic protons of the acylated primary OH. However, the spectrum was rather complex due to the presence of (at least) two conformers in solution.[9] One of the methylene protons at C-3 appeared as two overlapping dd at δ 2.72 and 2.74 (J = 17.0 and J = 3.0 Hz), the methine proton at C-2 gave two signals at δ 5.48 and 5.50 (dd, J = 11.5, 3.0 Hz), and the rhamnose methyl showed two doublets at δ 1.17 and 1.19 (J = 7 Hz). The ^{13}C-NMR spectrum exhibited the signals of only one conformer and was similar to that of naringin, with the difference that C-6″ was shifted to δ 63.54 (from δ 60.52 in **9**) and that additional signals were observed for the two carboxyl functions at δ 166.75 and 166.83, for the two methylene carbons at δ 42.27 and 64.50 and for an alkyl-substituted benzene ring.

Hydrogenation of **10** gave naringin 6″-*O*-malonate (**8**) in quantitative yield, and the ^{13}C-NMR spectrum was identical to that published.[8] Also the ^{1}H-NMR spectrum was very similar, except that in our hands some signals were split by the presence of conformers in solution (see the Experimental Section). At 80 °C the spectrum still showed split signals with gradual appearance of signals due to naringin 6″-*O*-acetate (**11**) formed by thermal decarboxylation. This transformation was complete after 2 h at 110 °C, in agreement with the behavior of other malonic esters of flavonoid glycosides.[10] The ^{1}H- and ^{13}C-NMR spectra were identical to those of an authentic sample of **11** synthesized for comparison by reacting naringin with vinylacetate in the presence of subtilisin.[11]



8 : R = $COCH_2COOH$
9 : R = H
10 : R = $COCH_2COOCH_2C_6H_5$
11 : R = $COCH_3$

In conclusion, *C. antarctica* lipase has been shown to be an efficient catalyst for the regioselective introduction of a benzyl malonate moiety into some representative flavonoid glycosides. The elaboration of the benzyloxycarbonyl group into a carboxy function was performed under catalytic hydrogenation conditions, thus allowing the sensitive malonylated glycosides to be isolated in pure form without need of chromatographic purifications. Having the advantage of being simple and mild, this procedure appears to be very convenient for the preparation of malonates of glycosides whose aglycons lack functional groups that can undergo reduction by catalytic hydrogenation.

Experimental Section

General Experimental Procedures. NMR spectra were recorded on a Bruker 300 AC instrument. FABMS spectra were run on a VG 7070 EQ-HF spectrometer equipped with its own source, operating at 8 keV with Xe gas, and in diethanolamine as matrix. *C. antarctica* lipase supported on acrylic resin (Novozym 453) was obtained from NOVO NORDISK. Subtilisin was activated as described.[11] TLC was performed on precoated Si gel 60 F_{254} plates from Merck and column chromatography on Si gel Merck 60 (70−230 mesh).

General Procedure for Acylation of Glycosides with Dibenzyl Malonate. To a solution of the flavonol glycoside (0.1 mmol) in anhydrous Me_2CO containing 10% pyridine (3 mL) were added dibenzyl malonate (15 equiv) and *C. antarctica* lipase (200 mg), and the

suspension was shaken at 45 °C and 250 rpm for 12 days. After filtration of the enzyme and evaporation of the solvent, the residue was washed repeatedly with hexane and then purified by column chromatography using the appropriate AcOEt/MeOH mixture.

Isoquercitrin 6″-(*O*-benzyl malonate) (4): obtained in 74% yield as a powder; mp 132−134 °C; $[\alpha]^{18}_D$ +3.6° (*c* 0.1, MeOH); ^{1}H NMR (DMSO-d_6, 80 °C) δ 7.56 (1H, d, J = 1.5 Hz, H-2′), 7.54 (1H, dd, J = 8, 1.5 Hz, H-6′), 7.25−7.40 (5H, m, OCH$_2$*Ph*), 6.85 (1H, d, J = 8 Hz, H-5′), 6.40 (1H, d, J = 1.5 Hz, H-6), 6.21 (1H, d, J = 1.5 Hz, H-8), 5.39 (1H, d, J = 7.5 Hz, H-1″), 5.08 (2H, s, O*CH*$_2$Ph), 4.26 (1H, dd, J = 11.5, 2.0 Hz, H-6″a), 4.02 (1H, dd, J = 11.5, 6.0 Hz, H-6″b), 3.1−3.4 (6H, m, H-2″, H-3″, H-4″, H-5″, and CO*CH*$_2$CO); ^{13}C NMR (DMSO-d_6, 80 °C) δ 177.4 (s, C-4), 166.03 (2s, malonyl CO), 164.12 (s, C-7), 161.2 (s, C-5), 156.5 and 156.4 (2s, C-2 and C-8a), 148.5 (s, C-4′), 144.75 (s, C-3′), 135.2, 128.4, 128.05, and 127.78 (s, C-1; 2d, C-2/6; d, C-4 and 2d, C-3/5, of OCH$_2$*Ph*), 133.1 (s, C-3), 121.55 (d, C-6′), 121.1 (s, C-1′), 116.20 (d, C-5′), 115.15 (d, C-2′), 103.95 (s, C-4a), 101.0 (d, C-1″), 98.68 (d, C-6), 93.56 (d, C-8), 76.16 (d, C-3″), 73.94 (2d, C-2″ and C-3″), 69.65 (d, C-4″), 66.12 (t, *CH*$_2$Ph), 64.02 (t, C-6″), 40.88 (t, CO*CH*$_2$CO).

Rutin 3″-(*O*-benzyl malonate) (6): obtained in 79% yield as an amorphous solid; $[\alpha]^{18}_D$ −1° (*c* 0.1, MeOH); ^{1}H NMR (DMSO-d_6, 80 °C) δ 7.5−7.6 (2H, m, H-6′ and H-2′), 7.48−7.31 (5H, m, OCH$_2$*Ph*), 6.89 (1H, d, J = 9 Hz, H-5′), 6.42 (1H, d, J = 1.5 Hz, H-6), 6.21 (1H, d, J = 1.5 Hz, H-8), 5.42 (1H, d, J = 7.5 Hz, H-1″), 5.19 (2H, s, O*CH*$_2$Ph), 4.72 (1H, t, J = 7.5 Hz, H-3″), 4.52 (s, H-1‴), 3.55 (2H, s, CO*CH*$_2$CO), 3.1−3.8 (7H, m, H-2″, H-4″, H-5″, H-2‴, H-3‴, H-4‴, and H-5‴); ^{13}C NMR (DMSO-d_6, 80 °C) δ 177.4 (s, C-4), 166.2 (2s, malonyl CO), 164.01 (s, C-7), 160.97 (s, C-5), 156.4 (2s, C-2 and C-8a), 148.27 (s, C-4′), 144.71 (s, C-3′), 135.66, 128.45, 128.10, and 128.04 (s, C-1; 2d, C-2/6; 2d, C-3/5; d, C-4, of OCH$_2$*Ph*), 133.19 (s, C-3), 121.53 (C-6′), 121.2 (s, C-1′), 116.23 (d, C-5′), 115.20 (d, C-2′), 103.94 (s, C-4a), 100.95 (d, C-1″), 100.42 (d, C-1‴), 98.64 (d, C-6), 93.61 (d, C-8), 76.37 (d, C-3″), 75.59 (d, C-5″), 74.85 and 74.02 (2d, C-2‴ and C-3‴), 70.12 (d, C-2″), 69.57 (d, C-4‴), 67.93 (d, C-5‴), 66.70 (d, C-6″), 66.30 (t, O*CH*$_2$Ph), 65.55 (d, C-4″), 41.10 (t, CO*CH*$_2$CO), 16.96 (q, C-6‴).

Naringin 6″-(*Q*-benzyl malonate) (10): obtained in 69% yield as a powder; mp 79−82 °C; $[\alpha]^{18}_D$ −58° (*c* 0.2, MeOH); ^{1}H NMR (DMSO-d_6, room temperature) δ 7.32 (7H, m, OCH$_2$*Ph*, H-3′, H-5′), 6.81 and 6.83 (2H, d, J = 7 Hz, H-2′/6′), 6.15 and 6.13 (1H, d, J = 1.5 Hz, H-6), 6.10 (1H, d, J = 1.5 Hz, H-8), 5.50 and 5.48 (1H, dd, J = 13.0, 3.0 Hz, H-2), 5.18−5.08 (4H, m, H-1″, H-1‴ and O*CH*$_2$Ph), 4.32 (1H, bd, J = 11.5 Hz, H-6″a), 4.08 (1H, dd, J = 11.5, 6.5 Hz, H-6″b), 3.80−3.15 (11H, m, H-3a, H-2″, H-3″, H-4″, H-5″, H-2‴, H-3‴, H-4‴, H-5‴, CO*CH*$_2$CO), 2.74 and 2.72 (1H, dd, J = 17.0, 3.0 Hz, H-3b), 1.19 and 1.17 (3H, d, J = 7 Hz, H$_3$-6‴); ^{13}C NMR (DMSO-d_6, room temperature δ 197.22 (s, C-4), 166.83 and 166.75 (2s, malonyl CO), 164.75 (s, C-7), 162.83 and 162.74 (2s, C-5 and C-8a), 157.48 (s, C-4′), 135.4, 128.38, 128.10, and 127.83 (s, C-1; 2d, C-2/6; 2d, C-3/5; d, C-4, OCH$_2$*Ph*), 129.0 (s, C-1′), 128.89 (2d, C-2′ and C-6′), 115.19 (2d, C-3′ and C-5′), 103.40 (s, C-4a), 100.56 (d, C-1‴), 97.28 (d, C-1″), 96.29 (d, C-6), 95.26 (d, C-8), 78.81 (d, C-2), 76.78 (d, C-3″), 76.25 (d, C-2″), 73.59 (d, C-5″), 71.72 (d, C-4‴), 70.29 (d, C-3‴), 70.21 (d, C-2‴), 69.79 (d, C-4″), 68.38 (d, C-5‴), 66.50 (t, O*CH*$_2$Ph), 63.54 (t, C-6″), 42.27 (d, C-3), 41.10 (t, CO*CH*$_2$CO), 17.60 (q, C-6‴).

General Procedure for Debenzylation of Glycoside Benzyl Malonate to Glycoside Malonates. A solution of the flavonol glycoside benzylmalonate (0.04 mmol) in 2 mL anhydrous THF with a catalytic amount of Pd/C (5%) was stirred for 3 days under H_2. The catalyst was filtered and solvent removed under vacuum at room temperature to afford the malonyl glycosides in quantitative yield.

Isoquercitrin 6″-*O*-malonate (1): crystals mp 219−221 °C, $[\alpha]^{18}_D$ + 4.3° (*c* 0.45, MeOH); for ^{1}H and ^{13}C NMR see Danieli.[3]

Rutin 3″-*O*-malonate (7): amorphous; $[\alpha]^{18}_D$ −1.5° (*c* 0.1, MeOH); ^{1}H NMR (DMSO-d_6, 80 °C) δ 7.65−7.55 (2H, m, H-6′ and H-2′), 6.88 (1H, d, J = 9 Hz, H-5′), 6.44 (1H, d, J = 1.5 Hz, H-6), 6.22 (1H, d, J = 1.5 Hz, H-8), 5.44 (1H, d, J = 7.5 Hz, H-1″), 4.76 (1H, t, J = 7.5 Hz, H-3″), 4.54 (s, H-1‴), 3.60 (2H, s, CO*CH*$_2$CO), 3.1−3.8 (7H, m, H-2″, H-4″, H-5″, H-2‴, H-3‴, H-4‴, and H-5‴); ^{13}C NMR (DMSO-d_6, room temperature) δ 178.4 (s, C-4), 167.6 and 166.4 (2s, malonyl CO), 164.10 (s, C-7), 161.19 (s, C-5), 156.8 and 156.5 (2s, C-2 and C-8a), 148.50 (s, C-4′), 144.29 (s, C-3′), 133.89 (s, C-3), 122.43 (d, C-6′), 121.92 (s, C-1′), 117.23 (d, C-5′), 114.90 (d, C-2′), 104.24 (s, C-4a), 101.12 (d, C-1″), 100.56 (d, C-1‴), 99.54 (d, C-6), 94.61 (d, C-8), 76.87 (d, C-3″), 75.59 (d, C-5″), 74.85 and 74.02 (2d, C-2‴ and C-3‴), 70.12 (d, C-2″), 69.28 (d, C-4‴), 67.73 (d, C-5‴), 66.20 (d, C-6″), 64.65 (d, C-4″), 41.01 (t, CO*CH*$_2$CO), 16.86 (q, C-6‴).

Naringin 6″-*O*-malonate (8): powder; mp 90−93 °C; $[\alpha]^{18}_D$ −88.4° (*c*, 0.25, MeOH); ^{1}H NMR (DMSO-d_6, room temperature) δ 7.34 and 6.81 (4H, AA′BB′ system, J = 7 Hz, H-2′/6′, H-3′/5′), 6.13 and 6.11 (1H, d, J = 1.5 Hz, H-6), 6.08 (1H, d, J = 1.5 Hz, H-8), 5.52 and 5.50 (1H, dd, J = 13.0, 3.0 Hz, H-2), 5.20 and 5.18 (1H, d, J = 6.5 Hz, H-1″), 5.10 (1H, bs, H-1‴), 4.32 (1H, bd, J = 11.5 Hz, H-6″a), 4.14 (1H, dd, J = 11.5, 6.5 Hz, H-6″b), 3.83−3.15 (11H, m, H-3a, H-2″, H-3″, H-4″, H-5″, H-2‴, H-3‴, H-4‴, H-5‴, CO*CH*$_2$CO), 2.74 and 2.72 (1H, dd, J = 17.0, 3.0 Hz, H-3b), 1.16 (3H, d, J = 7 Hz, H$_3$-6‴); ^{1}H NMR (DMSO-d_6, 80 °C) δ 7.33 and 6.82 (4H, AA′BB′ system, J = 7 Hz, H-2′, H-6′, H-3′, H-5′), 6.14 (1H, d, J = 1.5 Hz, H-6), 6.12 (1H, d, J = 1.5 Hz, H-8), 5.53 and 5.49 (1H, dd, J = 13.0, 3.0 Hz, H-2), 5.16 (1H, bs, H-1‴), 5.13 (1H, d, J = 6.5 Hz, H-1″), 4.39 (1H, bd, J = 11.5 Hz, H-6″a), 4.17 (1H, dd, J = 11.5, 6.5 Hz, H-6″b), 3.78−3.10 (11H, m, H-3a, H-2″, H-3″, H-4″, H-5″, H-2‴, H-3‴, H-4‴, H-5‴, CO*CH*$_2$CO), 2.81 and 2.78 (1H, dd, J = 17.0, 3.0 Hz, H-3b), 1.19 (3H, d, J = 7 Hz, H$_3$-6‴); ^{13}C NMR (DMSO-d_6, room temperature) δ 197.27 (s, C-4), 166.90 and 166.80 (2s, malonyl CO), 164.54 (s, C-7), 162.92 and 162.82 (2s, C-5 and C-8a), 157.30 (s, C-4′), 128.6 (s, C-1′), 128.46 (2d, C-2′ and C-6′), 115.23 (2d, C-3′ and C-5′), 103.44 (s, C-4a), 100.58 (d, C-1‴), 97.27 (d, C-1″), 96.33 (d, C-6), 95.28 (d, C-8), 78.88 (d, C-2), 76.83 (d, C-3″), 76.24 (d, C-2″), 73.56 (d, C-5″), 71.78 (d, C-4‴), 70.36 (2d, C-2‴and C-3‴), 69.67 (d, C-4″), 68.38 (d, C-5‴), 63.95 (t, C-6″), 42.31 (d, C-3), 41.18 (t, CO*CH*$_2$CO), 18.02 (q, C-6‴).

Naringin 6″-*O*-Acetate (11). To naringin (0.1 mmol) dissolved in anhydrous pyridine (2 mL) containing vinylacetate (0.43 mmol), subtilisin was added, and the suspension was shaken at 45 °C for 48 h (34% conver-

sion). Usual workup and purification by chromatography furnished **11**: crystals; mp 150−152 °C; $[\alpha]^{18}_{D}$ −90.4° (*c* 0.27, MeOH); ^{1}H NMR (DMSO-d_6, room temperature) δ 7.32 and 6.80 (4H, AA′BB′ system, J = 7 Hz, H-2′, H-6′, H-3′, H-5′), 6.12 (1H, d, J = 1.5 Hz, H-6), 6.09 (1H, d, J = 1.5 Hz, H-8), 5.54 and 5.52 (1H, dd, J = 11.5, 3.0 Hz, H-2), 5.19 and 5.17 (1H, d, J = 6.5 Hz, H-1″), 5.12 (1H, bs, H-1‴), 4.29 (1H, bd, J = 11.5 Hz, H-6″a), 4.05 (1H, dd, J = 11.5, 7.0 Hz, H-6″b), 3.80−3.10 (9H, m, H-3a, H-2″, H-3″, H-4″, H-5″, H-2‴, H-3‴, H-4‴, H-5‴), 2.75 (1H, dd, J = 17.0, 3.0 Hz, H-3b), 1.98 and 1.95 (3H, s, CO*CH*$_3$), 1.18 and 1.16 (3H, d, J = 6.5 Hz, H$_3$-6‴); ^{1}H NMR (DMSO-d_6, 80 °C) δ 7.30 and 6.82 (4H, AA′BB′ system, J = 7 Hz, H-2′, H-6′, H-3′, H-5′), 6.16 (1H, d, J = 1.5 Hz, H-6), 6.11 (1H, d, J = 1.5 Hz, H-8), 5.53 and 5.50 (1H, dd, J = 13.0, 3.0 Hz, H-2), 5.19 and 5.17 (1H, bs, H-1‴), 5.14 and 5.12 (1H, d, J = 6.5 Hz, H-1″), 4.35 (1H, bd, J = 11.5 Hz, H-6″a), 4.08 and 4.06 (1H, dd, J = 11.5, 6.5 Hz, H-6″b), 3.80−3.10 (9H, m, H-3a, H-2″, H-3″, H-4″, H-5″, H-2‴, H-3‴, H-4‴, H-5‴), 2.79 (1H, dd, J = 17.0, 3.0 Hz, H-3b), 1.93 (3H, s, COCH$_3$) 1.18 (3H, d, J = 7 Hz, H$_3$-6‴); ^{13}C NMR (DMSO-d_6, 80 °C) δ 197.25 (s, C-4), 170.44 (s, *CO*CH$_3$), 164.42 (s, C-7), 162.83 and 162.58 (2s, C-5 and C-8a), 157.50 (s, C-4′), 128.96 (s, C-1′), 128.50 (2d, C-2′ and C-6′), 115.17 (2d, C-3′ and C-5′), 103.38 (s, C-4a), 100.53 (d, C-1‴), 97.29 (d, C-1″), 96.27 (d, C-6), 95.28 (d, C-8), 78.71 (d, C-2), 76.70 (d, C-3″), 76.33 (d, C-2″), 73.65 (d, C-5″), 71.67 (d, C-4‴), 70.23 and 70.17 (2d, C-2‴ and C-3‴), 69.85 (d, C-4″), 68.36 (d, C-5‴), 63.17 (t, C-6″), 41.3 (d, C-3), 20.44 (q, CO*CH*$_3$), 17.92 (q, C-6‴).

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References and Notes

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