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Fast Galloylation of a Sugar Moiety: Preparation of Three Monogalloylsucroses as References for Antioxidant Activity. A Method for the Selective Deprotection of *tert*-Butyldiphenylsilyl Ethers

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Abstract—Three protected new gallotannins, namely the 6′-*O*-(tri-*O*-methylgalloyl)-2,3,4,6,1′,3′,4′-hepta-*O*-acetylsucrose, the 6′-*O*-(tri-*O*-methylgalloyl)-2,3,4,6,1′,3′,4′-hepta-*O*-benzoylsucrose and the 6,6′-di-*O*-*tert*-butyldiphenylsilyl-1′-*O*-(tri-*O*-methylgalloyl)-2,3,4,3′,4′-penta-*O*-acetylsucrose have been prepared in four short sequences from sucrose. Methods for rapid galloylation have been studied in order to avoid simultaneous acyl transfer reactions. A method for the deprotection of a *tert*-butyldiphenylsilyl ether has been developed which avoids the intramolecular migration of a benzoate group.

Introduction

Gallotannins are heterogeneous glycosidic esters of gallic acid and its *O*-linked derivatives (*meta*-depside linkage), which are secondary metabolites of higher plants.[1,2] They are efficient antioxidants by reason of their ability to trap reactive oxygen species involved in cardiovascular diseases and cancer.[3] The strong contribution of the galloyl or similar polyphenolic groups have been demonstrated several times.[4,5] The sugar moiety also displays an important role which is demonstrated by the observation that most of the gallotannins have a stronger effect than the smaller polyphenol molecules.[5,6] As a general rule, the antioxidative activity of each tannin is dependent on the type and number of the phenolic groups in the molecule.[5] Nevertheless, the activity is dependent on other factors such as the position of the galloyl groups,[7] the active oxygen species (superoxide anions, hydroxyl radicals, singlet oxygen),[6] the interaction with coexisting compounds[8] or the alcohol core.[5,6,8]

At the end of the 1980s, five new gallotannins have been isolated[2] from commercial rhubarbs, each one displaying a sucrose core acylated by one gallate unit (respectively the 6′-*O*, 4′-*O*, 6-*O*, 1′-*O* and 2-*O*-monogalloylsucrose). The importance of such derivatives has been emphasised by Dangles et al.,[3] who prepared and tested some polygalloylsucroses. We know of no other reference to galloylated sucrose, which is surprising when we consider the good antioxidant ability of these compounds. Many studies have been done with the glucose core,[5,6] but only few natural galloylated furanoses have been isolated.[6,13,14] As an example, the 1-*O*-galloylfructose extracted from a rhubarb[13] or hamamelitannins[6] whose oxidation tests have shown that furanose rings can play an important role in scavenging hydroxyl radicals. This lack of study has stimulated us to concentrate our work in the fructose unit of the sucrose. With the aim of comparing the effect of the position of the galloyl group on its antioxidant activity, we have functionalised selectively each one of the primary hydroxyl groups of the fructose unit of sucrose.

We were stimulated to enlarge the collection of known gallotannins, with the aim of studying the mechanistic aspects of the oxidation reaction. Such tests need a comparison with a specific reference. The most employed references are gallic acid and various ether gallates.[5,6] As a first target we proposed to construct molecules more similar to gallotannins and with all the supposed active groups protected. A methylation of the phenolic groups[9,10,11] induces a loss of antioxidative activity.[12] The introduction of only one tri-*O*-methyl galloyl unit into a specific place of a protected sucrose should avoid the intra- and/or intermolecular stacking interactions suspected between the galloyl units.[3]

Keywords: sucrose; galloylation; gallotannins; *tert*-butyldiphenylsilyl ether (deprotection of).
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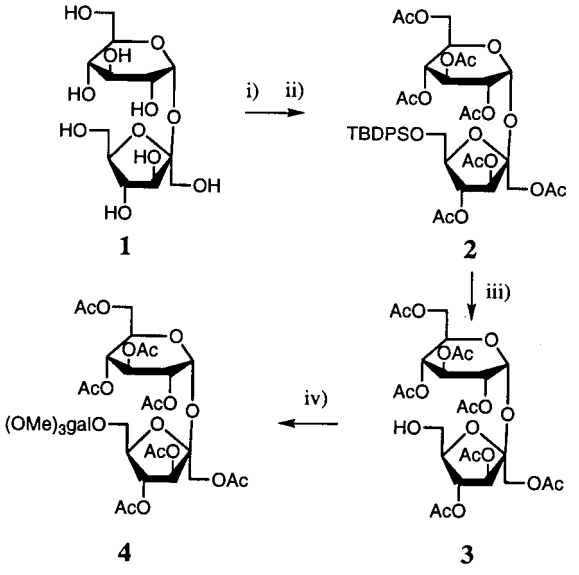
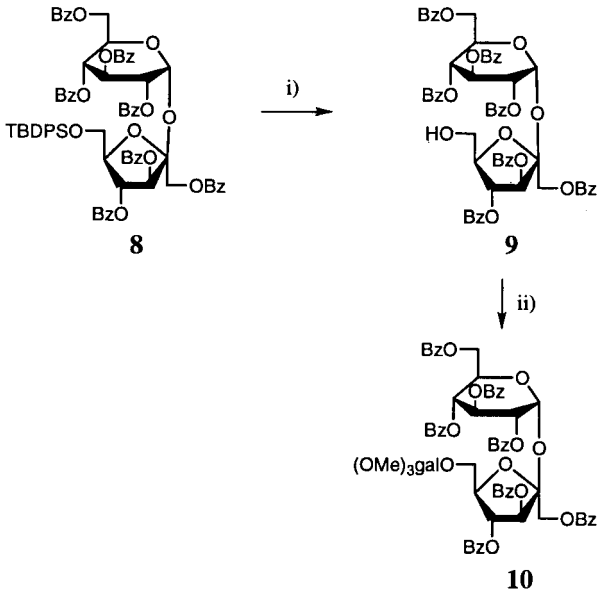


Scheme 1. (i) TBDPSCl, pyr.; (ii) Ac_2O, pyr.; (iii) nBu$_4$NF, THF; (iv) (OMe)$_3$galloyl chloride, TMEDA, CH_2Cl_2.

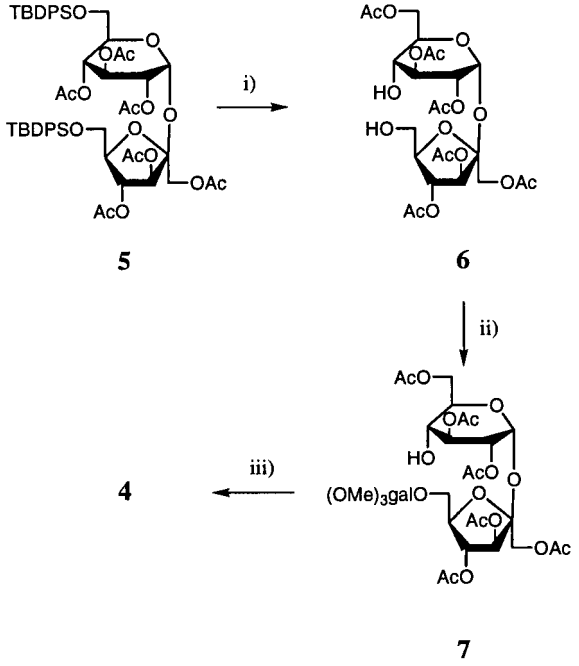


Scheme 3. (i) Br_2 in MeOH, reflux; (ii) (OMe)$_3$galloyl chloride, TMEDA, CH_2Cl_2.

We have prepared three references, composed of a sucrose core acylated with one tri-*O*-methylgalloyl in the position 1′ or 6′ of the fructose moiety, and with the hydroxyl groups fully protected (benzoates, acetates and/or silyloxy groups). One of the routes required a specific desilylation without migration of an adjacent benzoyl group. We present here a procedure, using bromine in methanol, which has allowed us to obtain our target compound.

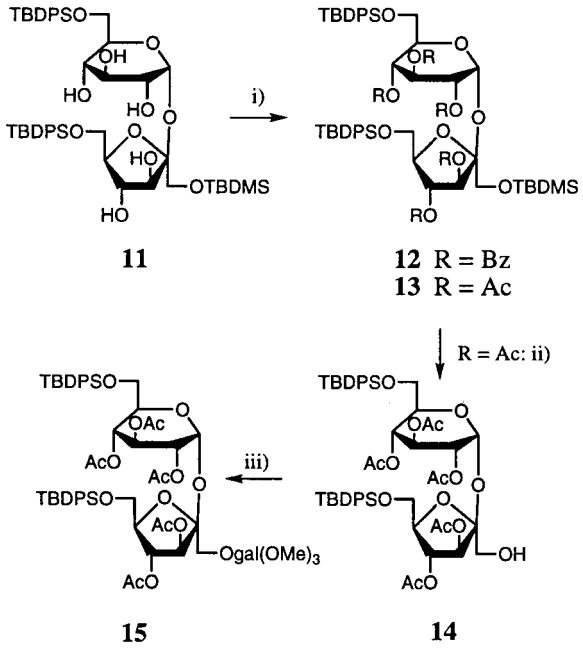
Results and Discussion

The first way to our targets (Scheme 1) consisted of a selective silylation of the 6′ hydroxyl group of the sucrose (**1**) followed by an acetylation by acetic anhydride in pyridine, as described in the literature,[15] leading to **2**. Selective deprotection of the silyloxy function using tetrabutylammonium fluoride in THF gave the expected alcohol **3** with a moderate yield (50%) by reason of the formation of products resulting from acyl migration and fluorolysis of acetate groups. First attempts at the esterification of partially protected sucrose by tri-*O*-methyl galloylchloride in a mixture of dimethylformamide–triethylamine in the presence of 4-dimethylaminopyridine[3] led to the expected compounds but with again only moderate yields (32–64% depending on the initial). An adaptation of the recent method described by Oriyama et al.,[16] consisting in a fast acylation in the presence of TMEDA, afforded the expected galloylated sucroses with medium to good yields. Following this procedure, reaction of **3** with the trimethylgalloyl chloride led to the 6′-tri-*O*-methylgalloyl **4** with the medium yield of 52%.



Scheme 2. (i) nBu$_4$NF, THF; (ii) (OMe)$_3$galloyl chloride, TMEDA, CH_2Cl_2; (iii) Ac_2O, pyr.

Compound **4** was also obtained from sucrose (Scheme 2), in just one extra step than the previous way but with better overall yields. An attempt to remove the silyloxy groups of polyacetylated 6,6′-di-*O*-silyloxy sucrose **5**[15] using tetrabutylammonium fluoride in THF occurred (**6**) with the migration of one acetate. Indeed, a study of the ^{1}H NMR spectrum of the obtained derivative showed a triplet at 3.46 ppm, that we have attributed to the proton H-4 after some irradiation experiments. We have confirmed this migration by the observation of the two doublets of doublets, respectively at 4.26 and 4.48 ppm, attributed to the protons H-6 or H-6′. These signals were too deshielded to belong to an hydroxymethylene, but are typical of an acetylated one. Unfortunately, it was impossible to determine at that time if the migration had occurred from the position O-4 to the position O-6 or O-6′. An acylation of **6** using 2 equiv. of galloyl chloride, and following the same procedure described for **3**, led to a major product (84%) whose NMR spectral data agree with the monogalloylsucrose **7**. In particular, the signal at 7.31 ppm (two aromatic protons) and the singlets at around 3.9 ppm (nine



Scheme 4. (i) Ac_2O, pyr. or BzCl, pyr.; (ii) I_2 in MeOH, reflux; (iii) $(OMe)_3$galloyl chloride, TMEDA, CH_2Cl_2.

protons in total) proved the presence of only one galloyl function. Here also, it was impossible to certify which one was the newly acylated atom (O-6 or O-6′). Some irradiation experiments have confirmed the free hydroxyl function at C-4. A classical acetylation of **7** led to a compound whose physical data (optical rotation, ^1H and ^{13}C NMR spectra) were identical to those of the previously obtained 6′-galloyl sucrose **4**. This result has led us to suppose that the intermediate **6** was the 6′-OH free sucrose, and that **7** was tri-*O*-methyl galloylated in 6′. During the formation of **6**, the acetate had migrated from O-4 to O-6 under the influence of the fluoride.

We have also prepared the benzoylated 6′-galloyl sucrose **10** in order to carry out further experiments (Scheme 3) with the aim of confirming that the protective groups of the sucrose unit would not influence the proposed oxidation tests of our references.

We have developed in the laboratory a new method of deprotection of *tert*-butyldiphenylsilyloxy (TBDPS) groups, occurring without migration of the esters groups. This method is derived from the recently published procedure of Vaino and Szarek[17] who have demonstrated its efficiency for the deprotection of *tert*-butyldimethylsilyl (TBDMS) ethers using iodine in methanol. This procedure was unsuccessful with the compound **8**[15] as the OTBDPS is usually more stable than an OTBDMS.[18] By using a smaller halogen (e.g. bromine), we have been able to deprotect the TBDPS function of **8**, with good selectivity (69%) and without observation of any migration. Unfortunately, as the mechanism of the reaction was suspected to occur with the formation of acid-like species and traces of HBr, degradation of the *O*-glycosidic link of the sucrose was expected and this fact can explain the somewhat disappointing yield. Galloylation of the so obtained alcohol **9** in the presence of TMEDA led to the expected **10** with a good yield (85%).

As a continuation of studies already carried out in our laboratory,[19] and with the aim of functionalising selectively the 1′ position of the sucrose, we have used (Scheme 4) the yet-obtained 6,6′-di-*O*-silyloxy sucrose, for a selective protection of the 1′-hydroxyl free function of the sucrose. The action of TBDMSCl in pyridine in the presence of 4-dimethylaminopyridine led to the pentol **11**, which has been characterized as its pentabenzoate **12**. An acetylation of **11** gave an inseparable mixture of two compounds, containing as a major one the pentaacetate **13**. The reaction with a solution of iodine in methanol gave the expected **14** whose physical data are in agreement with the compound described in the literature.[20] The galloylation of **14** by the procedure previously described for **3** led to **15** (78%).

Conclusion

We have selectively prepared the precursors of two new gallotannins, containing one phenolic unit specifically at the 1′ or the 6′ position of the fructose unit of the sucrose. These compounds have been obtained in four short-step syntheses, using in particular a new method for the fast galloylation of sugar moieties.

Experimental

General

Reagents and solvents were purified before use. Flash chromatography was performed on silica gel from Macherey–Nagel (Kieselgel 60 M). Preparative TLC was performed on glass plates coated with 1 mm of silica gel (Macherey–Nagel, Kieselgel DGF_{254}). Analytical TLC: Aluminium-backed silica gel Merck 60 F_{254}. Optical rotations were measured at 20°C on a Perkin–Elmer 241 polarimeter (1 dm cell). NMR spectra were recorded on a Bruker AMX-400 apparatus (^1H at 400 MHz and ^{13}C at 100 MHz) in $CDCl_3$ with chemical shift values (δ) in ppm downfield from tetramethylsilane. Microanalyses were performed by the IST analytical services in Lisbon using a combustion apparatus. Mass spectroscopies were performed by the 'Unidade de Espectroscopía de Masas' de Santiago de Compostela, Spain.

6′-*O*-*tert*-Butyldiphenylsilyl-2,3,4,6,1′,3′,4′-hepta-*O*-acetylsucrose (2). This compound was prepared as described in the literature.[15] $[\alpha]_D=+51.6$ (*c* 1, $CHCl_3$), Lit.[15] +50 (*c* 1.2, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 7.66 (m, 4H, Ar), 7.41 (m, 6H, Ar), 5.64 (d, *J*=3.7 Hz, 1H, H-1), 5.52 (t, *J*=5.7 Hz, 1H, H-4′), 5.40 (m, 1H, H-3), 5.40 (d, *J*=5.4, 1H, H-3′), 5.03 (t, *J*=9.9 Hz, 1H, H-4), 4.83 (dd, *J*=10.4, 3.7 Hz, 1H, H-2), 4.19 (d, *J*=12.3 Hz, 1H, H-1′a), 4.15 (m, 3H, H-5, H-6a and H-5′), 4.14 (d, 1H, H-1′b), 3.95 (dd, *J*=7.8, 1.4 Hz, 1H, H-6b), 3.87 (dd, *J*=11.0, 5.4 Hz, 1H, H-6′a), 3.83 (dd, *J*=11.0, 5.8 Hz, 1H, H-6′b), 2.14, 2.10, 2.09, 2.05, 2.01, 1.98, 1.97 (7s, 3H each, OCOMe), 1.06 (s, 9H, ^{t}Bu). ^{13}C NMR ($CDCl_3$) δ 19,10 (CMe_3), 20.45, 20.47, 20.53, 20.55, 20.68 (Me), 26.64 (CMe_3), 61.50, 62.80, 63.80 (C-6, C-1′ and C-6′), 68.00, 68.20, 69.70, 70.10 (C-2, C-3, C-4 and C-5), 75.00, 76.10 (C-3′ and C-4′), 81.30 (C-5′), 89.60 (C-1), 103.60 (C-2′), 127.70, 129.80, 132.80, 132.90,

135.50 (Ar), 169.40, 169.70, 169.80, 169.90, 170.00, 170.50 (CO).

2,3,4,6,1′,3′,4′-Hepta-*O*-acetylsucrose (3). To a solution of **2** (250.0 mg, 0.29 mmol) in dry THF (7 mL) was added, under argon, tetrabutylammonium fluoride (1.8 equiv., 135.0 mg). When the reaction mixture showed no more starting material (TLC in AcOEt/hexane, 3/2), the THF was evaporated. Water was then added, and the organic compounds were extracted with dichloromethane. After drying and concentration, a purification by flash chromatography gave the expected but unstable 6′-free sucrose **3** (91.0 mg, 50%). ^{1}H NMR ($CDCl_3$) δ 5.68 (d, J=3.5 Hz, 1H, H-1), 5.47 (m, 3H, H-3, H-3′ and H-4′), 5.09 (t, J=9.4 Hz, 1H, H-4), 4.88 (dd, J=12.0, 3.5 Hz, 1H, H-2), 4.18 (d, J=11.7 Hz, 1H, H-1′a), 4.16 (m, 4H, H-5, H-6a, H-6b and H-5′), 4.10 (d, 1H, H-1′b), 3.84 (dd, J=12.8, 2.8 Hz, 1H, H-6′a), 3.68 (dd, J=12.8, 4.4 Hz, 1H, H-6′b), 2.70 (wide signal, 1H, OH), 2.19, 2.13, 2.11, 2.10, 2.08, 2.05, 2.02 (7s, 3H each, OCOMe). ^{13}C NMR ($CDCl_3$) δ 20.41, 20.45, 20.47, 20.50, 20.55, 20.61, 20.87 (Me), 61.10, 61.40, 63.80 (C-6, C-1′ and C-6′), 67.90, 68.60, 69.30, 70.10 (C-2, C-3, C-4 and C-5), 73.70, 76.00 (C-3′ and C-4′), 81.60 (C-5′), 89.90 (C-1), 103.20 (C-2′), 169.40, 169.80, 169.90, 170.00, 170.40, 170.50, 170.60 (CO).

6′-*O*-(Tri-*O*-methylgalloyl)-2,3,4,6,1′,3′,4′-hepta-*O*-acetylsucrose (4). *First way: general procedure.* To a solution of TMEDA (2.0 equiv., 94.2 μL) in dry dichloromethane (1 mL), was added molecular sieves 3 Å (165 mg), and then a solution of 200.0 mg of **3** dissolved in dry dichloromethane (6 mL) under argon. The mixture was cooled to −78°C, and then tri-*O*-methylgalloyl chloride (2.5 equiv., 179 mg) in dry dichloromethane (1 mL) was added. The reaction mixture was allowed to warm until room temperature, then stirred overnight. After neutralization by a solution of phosphate buffer (pH 7) and extraction with dichloromethane, the combined organic phases were washed with brine, dried and concentrated. A purification of the crude by flash chromatography (AcOEt/hexane, 1/1) led to the expected **4** (135.0 mg, 52%). $[\alpha]_D$=+36.9 (c 0.4, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 7.33 (m, 2H, Ar), 5.76 (d, J=3.6 Hz, 1H, H-1), 5.47 (m, 3H, H-3, H-3′ and H-4′), 5.07 (t, J=9.6 Hz, 1H, H-4), 4.87 (dd, J=11.8, 3.4 Hz, 1H, H-2), 4.63 (dd, J=11.6, 6.8 Hz, 1H, H-6′a), 4.51 (dd, J=11.6, 5.6 Hz, 1H, H-6′b), 4.40–4.13 (m, 6H, H-5, H-6a, H-6b, H-5′, H-1′a and H-1′b), 3.93 (s, 6H, ArO*Me*), 3.91 (s, 3H, ArO*Me*), 2.18, 2.12, 2.11, 2.10, 2.08, 2.03, 2.02 (7s, 3H each, OCOMe). ^{13}C NMR ($CDCl_3$) δ 20.38, 20.46 (Me), 56.15 (ArO*Me*), 60.75 (ArO*Me*), 61.64, 62.78, 64.31 (C-6, C-1′ and C-6′), 68.00, 68.49, 69.39, 70.16 (C-2, C-3, C-4 and C-5), 75.53, 75.80 (C-3′ and C-4′), 79.07 (C-5′), 90.03 (C-1), 104.15 (C-2′), 107.08, 124.40, 142.66, 153.07 (Ar), 165.76, 169.59, 169.77, 169.90, 170.08, 170.21, 170.71 (CO); HRMS Calcd for $C_{36}H_{46}O_{22}$: 830.2480. Found: 830.2484.

Second way. Acetylation of **7** in the presence of 4-DMAP, followed by a purification on silica gel (AcOEt/hexane, 2/1) gave the previously reported **4** (90%).

6,6′-Di-*O*-*tert*-butyldiphenylsilyl-2,3,4,1′,3′,4′-hexa-*O*-acetylsucrose (5). This compound was prepared as described in the literature.[15] $[\alpha]_D$=+54.4 (c 1, $CHCl_3$), Lit.[15] +54.0 (c 1.2, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 7.66–7.60 (m, 8H, Ar), 7.43–7.27 (m, 12H, Ar), 5.65 (d, J=3.5 Hz, 1H, H-1), 5.38 (m, 4H, H-3, H-4, H-3′ and H-4′), 4.82 (dd, J=9.5, 3.5 Hz, 1H, H-2), 4.31 (d, J=12.0 Hz, 1H, H-1′a), 4.23 (d, 1H, H-1′b), 4.00 (d, J=9.0 Hz, 1H, H-5′), 3.81 (m, 2H, H-6′a and H-6′b), 3.63 (d, J=11.5 Hz, 1H, H-6a), 3.52 (d, 1H, H-6b), 2.11, 2.09, 2.07, 2.04, 2.02, 1.84 (6s, 3H each, OCOMe), 1.02 (s, 18H, ^{t}Bu). ^{13}C NMR ($CDCl_3$) δ 19,11 (CMe_3), 20.17, 20.47, 20.57, 20.74 (Me), 26.65, 26.67 (CMe_3), 61.30, 62.20, 63.90 (C-6, C-1′ and C-6′), 68.00, 70.20, 70.50, 70.60 (C-2, C-3, C-4 and C-5), 75.10, 76.20 (C-3′ and C-4′), 81.90 (C-5′), 90.50 (C-1), 104.50 (C-2′), 127.60, 127.62, 127.70, 129.50, 129.60, 129.70, 132.90, 135.40, 135.60, 135.63 (Ar), 169.10, 169.62, 169.64, 170.10, 170.20, 170.60 (CO); Anal. Calcd for $C_{56}H_{70}O_{17}Si_2$ (1070.42): C, 62.78; H, 6.59. Found C, 62.71; H, 6.86.

2,3,6,1′,3′,4′-Hexa-*O*-acetylsucrose (6). To a solution of **5** (0.5 g, 0.5 mmol) in anhydrous THF (10 mL) under argon was added 0.3 mg (2.5 equiv.) of tetrabutylammonium fluoride. After 2.5 h of stirring, TLC (AcOEt/hexane, 2/1) showed no trace of the starting material. Evaporation of the solvent followed by purification on silica gel (AcOEt/hexane, 2/1, then AcOEt) gave the title compound **6** (219.0 mg, 79%). $[\alpha]_D$=+36.9 (c 1, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 5.55 (d, J=3.6 Hz, 1H, H-1), 5.40 (m, 2H, H-3′ and H-4′), 5.23 (t, J=4.8–5.2 Hz, 1H, H-3), 4.76 (dd, J=10.4, 3.6 Hz, 1H, H-2), 4.48 (dd, J=12.8, 3.6 Hz, 1H, H-6a), 4.26 (dd, J=12.8, 2.4 Hz, 1H, H-6b), 4.10 (d, J=11.6–12.0 Hz, 1H, H-1′a), 4.04 (m, 2H, H-5 and H-5′), 4.00 (d, 1H, H-1′b), 3.77 (dd, J=12.8, 2.8 Hz, 1H, H-6′a), 3.60 (dd, J=12.8, 4.0 Hz, 1H, H-6′b), 3.46 (t, J=9.6 Hz, 1H, H-4), 2.11, 2.07, 2.05, 2.04, 2.03, 2.03 (6s, 3H each, OCOMe). ^{13}C NMR ($CDCl_{3**}$) δ 20.28, 20.35, 20.37, 20.44, 20.47, 20.56 (Me), 61.26, 62.43, 63.53 (C-6, C-1′ and C-6′), 68.47, 70.17, 71.11, 71.62 (C-2, C-3, C-4 and C-5), 73.89, 76.03 (C-3′ and C-4′), 81.69 (C-5′), 90.26 (C-1), 103.28 (C-2′), 170.12, 170.24, 170.29, 170.81, 171.13, 171.80 (CO); Anal. Calcd for $C_{24}H_{34}O_{17}$ (594.18): C, 48.49; H, 5.76. Found C, 48.17; H, 5.65.

6′-*O*-(Tri-*O*-methylgalloyl)-2,3,6,1′,3′,4′-hexa-*O*-acetylsucrose (7). The reaction of galloylation of **6** (133.0 mg, 0.2 mmol) was carried out according to the general procedure given for compound **3** (149 mg, 84%). $[\alpha]_D$=+28.7 (c 1.2, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 7.31 (m, 2H, Ar), 5.64 (d, J=3.6 Hz, 1H, H-1), 5.46 (m, 2H, H-3′ and H-4′), 5.40 (t, J=9.6 Hz, 1H, H-3), 4.79 (dd, J=10.4, 3.2–3.6 Hz, 1H, H-2), 4.47 (dd, J=14.0, 4.8 Hz, 1H, H-6 or H-6′), 4.40 (m, 2H, H-6 and H-6′, or H-5 and H-5′), 4.31 (dd, J=12.4, 1.6 Hz, 1H, H-6 or H-6′), 4.22 (d, J=12.4 Hz, 1H; H-1′a), 4.18 (d, 1H, H-1′b), 4.12 (m, 1H, H-5, H-5′, H-6 or H-6′), 4.10 (m, 1H, H-5, H-5′, H-6 or H-6′), 3.92 (s, 6H, OMe), 3.91 (s, 3H, OMe), 3.53 (t, 1H, H-4), 3.39 (s, 1H, OH), 2.15, 2.12, 2.11, 2.10, 2.08, 2.04 (6s, 3H each, OCOMe). ^{13}C NMR ($CDCl_3$) δ 20.23, 20.36, 20.41, 20.48, 20.62 (Me), 56.17, 56.19 (ArO*Me*), 60.77 (ArO*Me*), 62.55, 62.73, 64.68 (C-6, C-1′ and C-6′), 68.84, 70.30, 70.96, 71.82 (C-2, C-3, C-4 and C-5), 75.65, 75.83 (C-3′ and C-4′), 79.39 (C-5′), 90.44 (C-1), 104.31 (C-2′), 107.15, 124.40, 142.71, 153.07 (Ar), 166.03, 169.82,

170.00, 170.23, 170.48, 171.15, 171.61 (CO); Anal. Calcd for $C_{34}H_{44}O_{21}$ (788.24): C, 51.78; H, 5.62. Found C, 51.36; H, 5.62.

6′-*O*-*tert*-Butyldiphenylsilyl-2,3,4,6,1′,3′,4′-hepta-*O*-benzoylsucrose (8). This compound was prepared as described in the literature.[15] $[\alpha]_D$=+36.1 (*c* 1.2, $CHCl_3$), Lit.[15] +39 (*c* 1, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 8.01–7.27 (m, 45H, Ar), 6.17 (t, *J*=10.0 Hz, 1H, H-3), 6.06 (t, *J*=6.2 Hz, 1H, H-4′), 6.02 (d, *J*=3.6 Hz, 1H, H-1), 5.93 (t, 1H, H-3′), 5.72 (t, *J*=10.0 Hz, 1H, H-4), 5.41 (dd, *J*=10.4, 3.6 Hz, 1H, H-2), 4.65 (d, *J*=11.9 Hz, 1H, H-1′a), 4.59 (m, 1H, H-5), 4.54 (d, 1H, H-1′b), 4.33 (m, 2H, H-6a and H-5′), 4.21 (dd, *J*=12.5, 3.1 Hz, 1H, H-6b), 3.99 (d, *J*=5.3 Hz, 2H, H-6′a and H-6′b), 1.00 (s, 9H, ^{t}Bu). ^{13}C NMR ($CDCl_3$) δ 18.87, 21.21 (*C*Me_3), 26.51, 26.55 (C*Me*$_3$), 62.13, 63.72, 65.33 (C-6, C-1′ and C-6′), 68.88, 70.24, 71.02 (C-2, C-3, C-4 and C-5), 75.33, 76.68 (C-3′ and C-4′), 81.17 (C-5′), 90.15 (C-1), 103.94 (C-2′), 125.31–135.66 (Ar), 165.13, 165.34, 165.60, 165.66, 165.67, 165.75, 166.02 (CO).

2,3,4,6,1′,3′,4′-Hepta-*O*-benzoylsucrose (9). 850.0 mg (0.65 mmol) of **8** were refluxed in a solution of bromine 1% in methanol (4 mL) during 3 h. When TLC (AcOEt/hexane, 1/2) showed no more initial, the mixture was cooled and the excess of bromine was destroyed by a solution of 5% of $Na_2S_2O_3$. The aqueous layer was extracted by dichloromethane, and the organic layer was dried, concentrated, and purified on silica gel (AcOEt/hexane, 1/2) to give the heptabenzoate **9** (480 mg, 69%); $[\alpha]_D$=+65.4 (*c* 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 8.05–7.16 (m, 35H, Ar), 6.22 (m, 2H, H-1 and H-3), 6.03 (t, *J*=5.9 Hz, 1H, H-4′), 5.97 (t, 1H, H-3′), 5.78 (t, *J*=10.0 Hz, 1H, H-4), 5.34 (dd, *J*=10.4, 3.5 Hz, 1H, H-2), 4.72 (d, *J*=11.8 Hz, 1H, H-1′a), 4.61 (m, 1H, H-5), 4.56 (d, 1H, H-1′b), 4.22 (m, 3H, H-6a, H-6b and H-5′), 3.81 (m, 2H, H-6′a and H-6′b), 3.19 (br t, 1H, OH). ^{13}C NMR ($CDCl_3$) δ 60.80, 61.74, 65.54 (C-6, C-1′ and C-6′), 68.60, 69.24, 69.79, 71.94 (C-2, C-3, C-4 and C-5), 74.88, 77.99 (C-3′ and C-4′), 81.54 (C-5′), 90.80 (C-1), 104.43 (C-2′), 128.33–133.75 (Ar), 165.15, 165.63, 165.67, 165.74, 166.14, 167.03 (CO); Anal. Calcd for $C_{61}H_{50}O_{18}$ (1070.30): C, 68.41; H, 4.71. Found C, 68.14; H, 4.68.

6′-*O*-(Tri-*O*-methylgalloyl)-2,3,4,6,1′,3′,4′-hepta-*O*-benzoylsucrose (10). The galloylation of **9** (500.0 mg, 0.47 mmol) as described previously, followed by a purification by flash chromatography (AcOEt/hexane, 1/2) afforded ester **10** (413.0 mg, 70%); $[\alpha]_D$=+36.4 (*c* 0.3, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 8.09–7.16 (m, 37H, Ar), 6.20 (m, 2H, H-1 and H-3), 5.96 (m, 2H, H-3′ and H-4′), 5.77 (t, *J*=10.0 Hz, 1H, H-4), 5.41 (dd, *J*=10.4, 3.0 Hz, 1H, H-2), 4.79–4.59 (m, 6H, H-5, H-5′, H-1′a, H-1′b, H-6′a and H-6′b), 4.50 (dd, *J*=12.5, 2.2 Hz, 1H, H-6a), 4.38 (dd, *J*=12.4, 2.3 Hz, 1H, H-6b), 3.91 (s, 3H, OMe), 3.85 (m, 6H, OMe). ^{13}C NMR ($CDCl_3$) δ 56.02 (ArO*Me*), 60.75 (ArO*Me*), 62.13, 64.01, 64.76 (C-6, C-1′ and C-6′), 68.87, 69.19, 69.98, 71.36 (C-2, C-3, C-4 and C-5), 76.74, 77.54 (C-3′ and C-4′), 79.06 (C-5′), 90.91 (C-1), 104.95 (C-2′), 107.04, 124.58, 128.40–133.77, 142.37, 152.99 (Ar), 165.23, 165.50, 165.69, 165.88, 165.99, 166.16 (CO); Anal. Calcd for $C_{71}H_{60}O_{22}$ (1264.36): C, 67.40; H, 4.78. Found C, 67.13; H, 4.69.

6,6′-Di-*O*-*tert*-butyldiphenylsilyl-1′-*O*-*tert*-butyldimethylsilyl-2,3,4,3′,4′-penta-*O*-benzoylsucrose (12). *tert*-Butyldimethylchlorosilane (0.7 g, 2.0 equiv.) was added to a solution of 1.9 g (2.3 mmol) of 6,6′-di-*O*-*tert*-butyldiphenylsilyl sucrose[15] in pyridine (35 mL) in the presence of a catalytic amount of 4-DMAP. After stirring overnight at room temperature under argon, the pyridine was evaporated. Chromatography (AcOEt) gave the 6,6′-di-*O*-*tert*-butyldiphenylsilyl-1′-*O*-*tert*-butyldimethylsilylsucrose (**11**; 1.5 g, 71%). Benzoylation in the presence of 4-DMAP, followed by purification on silica-gel (AcOEt/hexane, 1/4) gave **12** (1.7 g, 70%). $[\alpha]_D$=−4.8 (*c* 0.9, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 8.01–7.12 (m, 45H, Ar), 6.18–6.02 (m, 5H, H-1, H-3, H-4, H-3′ and H-4′), 5.46 (dd, *J*=9.8–10.2, 3.4–3.8 Hz, 1H, H-2), 4.32 (m, 2H, H-5 and H-5′), 4.04 (d, *J*=10.5 Hz, 1H, H-1′a), 3.97 (m, 2H, H-6ab or H-6′ab), 3.63 (d, 1H, H-1′b), 3.54 (d, *J*=11.1 Hz, 1H, H-6a or H-6′a), 3.45 (d, *J*=10.7 Hz, 1H, H-6b or H-6′b), 1.09, 1.08, 0.93 (3s, 9H each, ^{t}Bu), −0.01, −0.03 (2s, 3H each, $SiMe_2$); ^{13}C NMR ($CDCl_3$) δ −5.98, −5.86 ($SiMe_2$), 17.97, 18.86, 18.95 (*C*Me_3), 25.63, 25.75, 26.54, 26.57 (C*Me*$_3$), 60.90, 63.83, 65.18 (C-6, C-1′ and C-6′), 68.04, 71.12, 71.49 (C-2, C-3, C-4 and C-5), 75.04, 76.61 (C-3′ and C-4′), 80.45 (C-5′), 89.81 (C-1), 104.85 (C-2′), 127.48–135.85 (Ar), 164.85, 165.27, 165.58, 165.95, 166.10 (CO); Anal. Calcd for $C_{85}H_{92}O_{16}Si_3$ (1452.57): C, 70.22; H, 6.38. Found C, 70.31; H, 6.30.

6,6′-Di-*O*-*tert*-butyldiphenylsilyl-2,3,4,3′,4′-penta-*O*-acetylsucrose (14). Acetylation of **11** followed by a purification on silica-gel (AcOEt/hexane, 1/4) gave 1.7 g of a mixture of **13** contaminated by another product. This impure **13** was refluxed in a solution of iodine 1% in methanol (50 mL) during 1 h. After cooling, the reaction mixture was treated with $Na_2S_2O_5$ 1% and extracted with dichloromethane. The organic layer was washed by $Na_2S_2O_3$ 5%, dried and concentrated. After chromatography (AcOEt/hexane, 1/2), the product **14** (0.7 g, 41% in two steps) was obtained. $[\alpha]_D$=+46.8 (*c* 0.2, $CHCl_3$), Lit.[20] +50 (*c* 1, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 7.63–7.27 (m, 20H, Ar), 5.61 (d, *J*=3.6 Hz, 1H, H-1), 5.55 (t, *J*=5.1 Hz, 1H, H-4′), 5.38 (t, *J*=9.8–10.0 Hz, 1H, H-3), 5.32 (d, *J*=5.2 Hz, 1H, H-3′), 5.77 (t, *J*=10.0 Hz, 1H, H-4), 4.87 (dd, *J*=10.4, 3.7 Hz, 1H, H-2), 4.11 (m, 1H, H-5 or H-5′), 3.98 (m, 1H, H-5 or H-5′), 3.80 (m, 2H, H-6 or H-6′), 3.72 (d, *J*=12.6 Hz, 1H, H-1′a), 3.65 (d, *J*=12.7 Hz, 1H, H-1′b), 3.53 (dd, *J*=11.6, 1.6 Hz, 1H, H-6 or H-6′), 3.44 (dd, *J*=11.6, 3.8 Hz, 1H, H-6 or H-6′), 2.13, 2.10, 2.02, 2.01, 1.86 (5s, 3H each, OCOMe), 1.02, 1.01 (2s, 9H each, ^{t}Bu). ^{13}C NMR ($CDCl_3$) δ 18.94, 19.03 (*C*Me_3), 20.35, 20.39, 20.48, 20.59, 20.66 (Me), 26.52, 26.55, 26.58 (C*Me*$_3$), 61.55, 63.16, 64.21 (C-6, C-1′ and C-6′), 68.17, 70.07, 70.31, 70.46 (C-2, C-3, C-4 and C-5), 76.40, 77.89 (C-3′ and C-4′), 81.28 (C-5′), 90.59 (C-1), 105.86 (C-2′), 127.71, 127.77, 129.72, 129.81, 129.86, 132.85, 133.10, 133.13, 135.56, 135.59, 135.75, 135.79 (Ar), 169.37, 169.87, 170.28, 170.46, 170.79 (CO).

6,6′-Di-*O*-*tert*-butyldiphenylsilyl-1′-*O*-(tri-*O*-methylgalloyl)-2,3,4,3′,4′-penta-*O*-acetylsucrose (15). The galloylation of **14** (0.7 g, 0.7 mmol) as described previously, followed by a purification by flash chromatography (AcOEt/hexane, 1/2) led to the title compound **15** (0.6 g, 78%). $[\alpha]_D$=+48.5 (*c* 1, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ

7.61–7.27 (m, 22H, Ar), 5.65–5.31 (m, 5H, H-1, H-3, H-4, H-3′ and H-4′), 4.83 (dd, J=9.9, 3.6 Hz, 1H, H-2), 4.56 (d, J=12.4 Hz, 1H, H-1′a), 4.39 (d, 1H, H-1′b), 3.95–3.90 (m, 11H, OMe, H-5 and H-5′), 3.62 (d, J=11.7 Hz, 1H, H-6 or H-6′), 3.51 (d, J=11.1 Hz, 1H, H-6 or H-6′), 3.40 (m, 2H, H-6 or H-6′), 2.05, 2.02, 2.00, 1.99, 1.96 (5s, 3H each, OCOMe), 1.01, 1.00 (2s, 9H each, ^{t}Bu). ^{13}C NMR ($CDCl_3$) δ 18.91, 18.93 (CMe_3), 20.23, 20.27, 20.30, 20.51, 20.54 (Me), 25.53, 26.48 (CMe_3), 56.11, 56.23, 59.03 (ArO*Me*), 60.74, 62.81, 63.65 (C-6, C-1′ and C-6′), 69.96, 70.17, 70.47, 70.57 (C-2, C-3, C-4 and C-5), 75.02, 76.35 (C-3′ and C-4′), 82.32 (C-5′), 90.68 (C-1), 104.89 (C-2′), 106.96, 107.39, 124.40–135.74, 153.11 (Ar), 165.57, 169.22, 169.50, 169.67, 170.25, 170.30 (CO); HRMS Calcd for $C_{64}H_{78}O_{20}Si_2$ ($C_{64}H_{78}O_{20}Si_2$–Na): 1245.4522. Found: 1245.4490.

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