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Synthesis of acyl derivatives of salicin, salirepin, and arbutin

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ABSTRACT

The total synthesis of two natural phenolglycosides of the family *Salicaceae*, namely: populoside and 2-(β-D-glucopyranosyloxy)-5-hydroxy benzyl (3-methoxy-4-hydroxy) cinnamoate and nine not found yet in plants acyl derivatives of phenoglycosides: 2-(β-D-glucopyranosyloxy)-benzylcinnamoate, 2-(β-D-glucopyranosyloxy)-benzyl (4-hydroxy) benzoate, 2-(β-D-glucopyranosyloxy)-benzyl (3-methoxy-4-hydroxy) benzoate, 2-(β-D-glucopyranosyloxy)-5-hydroxy benzyl (3,4-dihydroxy) cinnamoate, 2-(β-D-glucopyranosyloxy)-5-hydroxy benzylcinnamoate, 2-(β-D-glucopyranosyloxy)-5-hydroxy benzyl (4-hydroxy) benzoate, 2-(β-D-glucopyranosyloxy)-5-hydroxy benzyl (3-methoxy-4-hydroxy) benzoate, 2-(β-D-glucopyranosyloxy)-5-benzoyloxy benzylbenzoate and 4-(β-D-glucopyranosyloxy)-phenylbenzoate, starting from readily available phenols and glucose was developed for the first time.

1. Introduction

The existence of phenolic glycosides in plants has been known for many years. The first, Salicin, was isolated in 1828 from willow bark.[1] Since then, many glycosides of different structures were isolated and identified.[2] These substances are of great interest for medicinal use because of their diverse biological activities. Plants of the family *Salicaceae* with large phenolglycoside content are widely used in traditional medicines all over the world and helpful for cure of pox, variola, pulmonary disease,[3] arthritis,[4] and other diseases. Most of phenolglycosides have anti-inflammatory activity[5] and antioxidant activity.[6,7]

The structure of *Salicaceae* phenolglycosides includes salicin (glucoside of salicylic alcohol) or salirepin (glucoside of gentisinic alcohol) acylated by different benzoic or cinnamic acids. It is not absolutely clear yet, but biological effects of phenolglycosides are more likely caused by the aglycon and especially by the nature of phenolic acid.

The presence of several phenolic acids in hydrolyzed methanol extracts from different species of *Salix* was established,[8] namely, *p*-hydroxybenzoic, vanillic, cinnanic, *p*-coumaric, ferulic, and caffeic acids. Obviously, such acids exist as free or as parts of glycosides.[9]

Indeed, it is known, that caffeic acid has anti-inflammatory and analgesic activity.[10] It has been found to be pharmacologically active as an antioxidant, antimutagenic, anticarcinogenic agent, and as a lipoxygenase inhibitor[11] and forms transitional metal ion-caffeic acid complexes.[12] Ferulic acid has antioxidant, antimicrobial, anti-inflammatory, anti-thrombosis, and anti-cancer activities.[13] *para*-Hydroxybenzoic acid, basic component of parabenes, shows antimicrobial activity,[14] antifungal, antimutagenic, antisickling, and estrogenic activity.[15] Vanillic acid has hepatoprotective effect[16,17] and exerts protective effects on cardiotoxic organisms.[18]

Thus, the structure of glycosides containing different combinations of salicin or salirepin moiety and one or more phenolic acids is the most predictable (Fig. 1). For confirmation of this, new phenolglycoside, consisting of salirepin and caffeic acid (**19**) was recently isolated.[6]

We previously reported the synthesis of some natural phenolglycosides of the family *Salicaceae*, containing cinnamic acids, namely, populosides A, B, and C.[19] We suggested a simple synthetic pathway for phenolglycosides of different structures. Thus, it would be reasonable to obtain glycosides of expected structure if they were not isolated from natural sources yet to make easier further phytochemical or biological investigations.

2. Results and discussion

The initial glycoside **1** was easily obtained by bromination of tetra-*O*-acetyl-*o*-cresylglycoside, which, in turn, was obtained by glycosylation of *o*-cresole.[20] Glycosides **2**, **3**, and **4** were obtained according to the method described previously.[19] Acylation of **1** was carried out by phenolic acids with sodium hydrocarbonate in DMF[21] medium (Scheme 1). Acyl-glycosides **5**–**6** were obtained in good yields.

Acylation of compound **2**, **3**, and **4** was carried out by acyl chloride of proper acid with pyridine to produce glycosides **7**–**14**.

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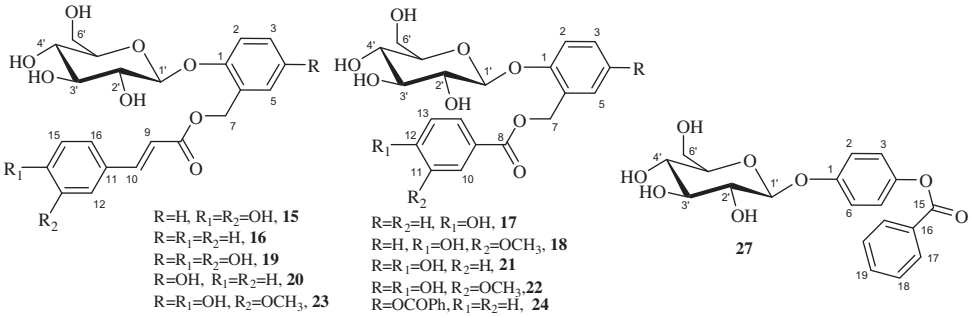
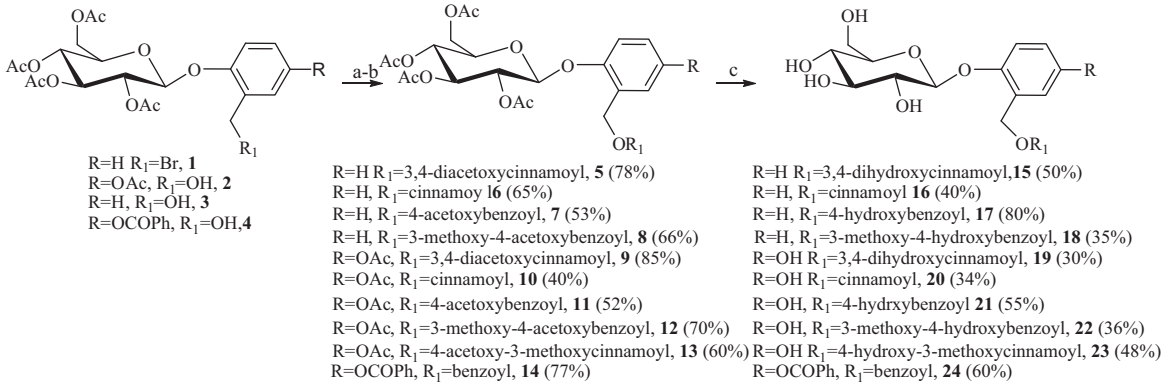
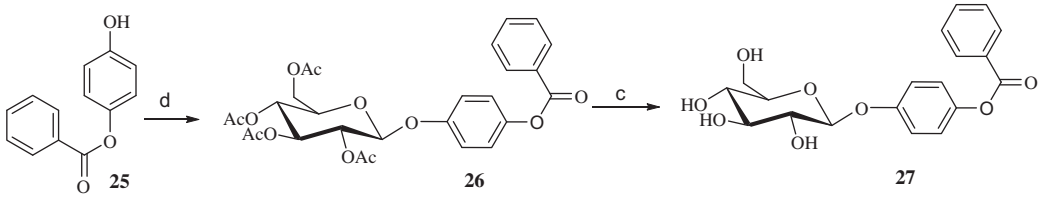


Figure 1. Structure of synthesized phenolglycosides **15**–**24**, **27**.



Scheme 1. Synthesis of 2-acyl phenolglycosides. Reagents and conditions: (a) acyl chloride of proper acid (3,4-acetoxy cinnamoyl chloride, cinnamoyl chloride, 4-acetoxy-3-methoxy cinnamoyl chloride, 4-acetoxybenzoyl chloride, 3-methoxy-4-acetoxy chloride, benzoylchloride), pyridine, $CHCl_3$, 24 h, 20 °C; (b) proper acid (3,4-acetoxy cinnamic acid, cinnamic acid, 4-acetoxybenzoic acid, 3-methoxy-4-acetoxybenzoic acid), $NaHCO_3$, DMF, RT, 24 h; (c) 36% HCl, $CHCl_3$, EtOH (1:1:3), 8–13 h, 30 °C.



Scheme 2. Synthesis of benzoyl-arbutin. Reagents and conditions: (d) acetobromoglucose, quinoline, Ag_2O, RT, 1 h; (c) as in the Scheme 1.

For the selective cleavage of acetyl groups in the presence of other acyl groups we applied the system, suggested previously: HCl–EtOH (96%)-chloroform in a molar ratio of HCl-glycoside 54:1. The reaction at 30 °C for 8–13 h resulted in successful acetyl group cleavage without significant cleavage of labile phenacyl groups and without breaking the glycosidic bond. All resulted glycosides **15**–**24** had β-configuration of anomeric center and *trans*-configuration of double bond esters of cinnamic acids (J = 15.9–16.2 Hz). Physicochemical data for populoside **15**, and glycoside **19** matched those reported.[6,22,23]

Glycoside **24**, 5-benzoylsalireposide, is isomeric to natural compound, 3′-benzoylsalireposide, found in *Symplocos racemosa*.[24] Natural compound showed strong inhibitory activity against snake venom phosphodiesterase I. Thus, substance **24** has potentially the same biological activity.

We also obtained benzoyl-arbutin **27** (Scheme 2), from acetate **26**. Substance **26** is well-known intermediate product for production of arbutin[25] and forms by glycosylation of monobenzoylhydroquinone **25**. Arbutin is natural phenolglycoside that nowadays is used in cosmetic industry.[26] Several attempts of 6′-O-benzoylarbutin synthesis were taken both by chemical[27,28] and enzymatic[29] means, but obtaining arbutin with aglycon benzoyl group **26** has not been previously reported.

In conclusion, we performed the first total synthesis of two known natural phenolglycosides, namely, populoside **15** and caffeoyl salirepin **19**. The resulted substances are identical to natural samples according to their physico-chemical properties. We also synthesized nine phenolglycosides of expected structure **15**–**17**, **19**–**23**, **26** that could be found in *Salicaceae* and have biological activity.

3. Experimental

3.1. General experimental procedures

Melting points, which are uncorrected, were determined using MP50 Melting point system (Mettler toledo). UV spectroscopic data were obtained with SF-102 spectrophotometer. IR spectra were recorded with IR Fourier spectrophotometer Spectrum BX II using

KBr disks. The ^{1}H and ^{13}C NMR spectra were recorded on Bruker-300 spectrometer at 300 and 75.5 MHz, respectively, in $CDCl_3$, DMSO-d_6, and MeOD-d_4 with TMS as an internal standard and Cr(*acac*)$_3$ as a relaxant. The chemical shifts are given in δ (ppm) and the spin–spin coupling constants (J) in hertz. Elemental analysis was performed on a EuroEA-3000 CHNS-O elemental analyzer. GC–MS analysis was performed using Aligent 7890A/5975C GC/MSD instrument, electron energy 70 eV. The ion source temperature was 230 °C, with the quadrupole temperature 150 °C and evaporator temperature 315 °C, employing a 30.000 × 0.25 mm × 0.25 μm HP—5MS fused-silica capillary column. Helium was used as carrier gas at a constant flow of 1 mL/min and an inlet temperature of 315 °C. The column temperature was initially held at 150 °C for 2 min and then the temperature was raised to 315 °C at a rate of 20 °C/min, followed by isothermal period of 25 min. The total run time was 35.25 min. TLC was performed using plates Silica gel 60 F254 Merck and Sorbfil-UV 254 using benzene-ethanol 9:1 (method A) or chloroform-methanol 4:1 (B) mixtures as eluents. HPLC analysis was carried out with the liquid chromatographer Agilent Compact LC with column 150 × 4.6 Exlips Plus C-18 (5 μm). Analysis was performed using 0.1% trifluoroacetic acid in H_2O–CH_3CN as mobile phase, at gradient elution (from 0% to 100% CH_3CN in 20 min) at a flow rate of 1 mL/min. Probe volume was 20 μL. UV detection was performed at 220 nm. Accurate mass measurement was performed on an Agilent 1200 series LC system coupled with an Agilent 6210 TOF mass spectrometer. Silica gel MN Kieselgel 60 0.04–0.063 mm was used for column chromatography. Commercially available solvents were used after drying with $CaCl_2$.

3.2. 2-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyloxy)-benzyl bromide (1)

The compound **1** was obtained according to[20] by gylcosylation of *o*-cresole and further radical bromination of 2-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyloxy)-toluene. Total yield 16% from *o*-cresole, mp 150–151 °C. UV λ_{max} (EtOH)/nm: 277. IR (KBr, ν_{max}/cm^{-1}): 2960, 1750, 1603, 1490, 1380, 1240, 1210, 1040, 108, 755. ^{1}H NMR (DMSO-d_6, 300 MHz) δ: 1.98, 2.01, 2.04 (s, 4 × 3H, Ac), 4.07 (m, 1H, H-5′), 4.21–4.30 (m, 2H, H-6′b, H-7b), 4.49–4.58 (m, 2H, C-6′a, C-7a), 4.99 (t, 1H, J = 9.6 Hz, H-4′), 5.12 (m, 1H, H-3′), 5.41 (m, 1H, H-2′), 5.56 (d, 1H, J = 7.8 Hz, H-1′), 7.06 (m, 2H, H-2, H-4), 7. 32 (m, 1H, H-3), 7.42 (d, 1H, J = 7.8 Hz, H-5). ^{13}C NMR (DMSO-d_6, 75.5 MHz) δ: 20.4 (4 × CH_3, Ac), 28.9 (CH_2, C-7), 61.8 (CH_2, C-6′), 68.0 (CH, C-4′), 70.2 (CH, C-2′), 70.9 (CH, C-3′), 71.8 (CH, C-5′), 97.0 (CH, C-1′), 114.9 (CH, C-2), 122.9 (CH, C-4), 126.5 (C, C-3), 130.2 (CH, C-6), 131.2 (CH, C-5), 154.1 (C, C-1), 169.0, 169.2, 169.4, 169.9 (4 × C, Ac).

3.3. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranozyloxy)-5-acetyloxy benzyl alcohol (2), 2-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranozyloxy)-benzyl alcohol (3) and 2-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranozyloxy)-5-benzoyloxy benzyl alcohol (4)

The compounds **2**, **3**, and **4** were obtained according to the method described earlier.[19]

3.4. Alkylation of glycoside 1. General method

A mixture of 0.150 g (0.29 mmol) of glycoside **1**, 0.35 mmol of proper acid, 0.35 mmol of sodium bicarbonate, and 1 mL of DMF was stirred at room temperature for 24–48 h. After reaction was complete (HPLC control), the reaction mixture was poured into 5 mL of water and stirred until obtained glycoside precipitated, filtered and recrystallized from ethanol. If glycoside did not precipitate, it was extracted twice with $CHCl_3$. $CHCl_3$ layer was washed with satd Na_2CO_3, water, dried over Na_2SO_4, and evaporated. The residue was recrystallized from ethanol.

3.4.1. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-benzyl (3,4-diacetoxy) cinnamoate (populoside hexaacetate) (5)

The compound **5** was obtained from 3,4-diacetoxy cinnamic acid. Yield 78%, mp 93–94 °C, lit.[22] 93–95 °C. UV λ_{max} (EtOH)/nm: 279. IR (KBr, ν_{max}/cm^{-1}): 2960, 1760, 1640, 1380, 1240, 1040, 907, 760. ^{1}H NMR ($CDCl_3$, 300 MHz) δ: 2.04, 2.06, 2.09, 2.12, 2.30 (s, 6 × 3H, Ac), 3.88 (m, 1H, H-5′), 4.16 (d, 1H, J = 10.8 Hz, H-6′b), 4.25 (dd, 1H, J = 5.0, 12.3 Hz, H-6′a), 5.08 (m, 1H, H-1′), 5.15–5.22 (m, 2H, H-4′, H-3′), 5.26–5.32 (m, 3H, H-2′, 2H-7), 6.35 (d, 1H, J = 15.9 Hz, H-9), 7.08 (m, 2H, H-2, H-4), 7.20 (d, 1H, J = 8.4 Hz, H-15), 7.26 (m, 2H, H-3, H-5), 7.36 (m, 2H, H-12, H-16), 7.62 (d, 1H, J = 16.2 Hz, H-10). ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 20.7 (6 × CH_3, Ac), 61.2 (CH_2, C6′), 61.9 (CH_2, C-7), 68.3 (CH, C-4′), 71.0 (CH, C-2′), 72.0 (CH, C-3′), 72.6 (CH, C-5′), 99.3 (CH, C-1′), 115.9 (CH, C-2), 119.0 (CH, H-9), 122.8 (CH, C-15), 123.6 (CH, C-4), 124.0 (CH, C-12), 126.2 (CH, C-6), 126.5 (CH,C-16), 129.5 (2 × CH, C-3, C-5), 133.2 (C, C-11), 142.4 (C, C-13), 143.2 (CH, C-10), 143.5 (C, C-14), 154.5 (C, C-1), 166.3 (C═O, C-8), 168.1, 169.4, 170.3 (6 × C═O, Ac).

3.4.2. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-benzylcinnamoate (6)

The compound **6** was obtained from cinnamic acid. Yield 65%, mp 116–118 °C. UV λ_{max} (EtOH)/nm: 278. IR (KBr, ν_{max}/cm^{-1}): 1750, 1640, 1500, 1370, 1210, 1030, 907. ^{1}H NMR ($CDCl_3$, 300 MHz) δ: 2.03, 2.04, 2.06, 2.09 (s, 4 × 3H, Ac), 3.85 (m, 1H, H-5′), 4.16 (d, 1H, J = 12.3 Hz, H-6′b), 4.25 (dd, 1H, J = 5.0, 12.3 Hz, H-6′a), 5.09 (d, 1H, J = 7.2, Hz, H-1′), 5.14–5.20 (m, 2H, H-4′, H-3′), 5.27–5.30 (m, 3H, H-2′, 2H-7), 6.45 (d, 1H, J = 15.3 Hz, H-9), 6.94 (m, 2H, H-2, H-4), 7.29 (m, 1H, H-5), 7.36 (m, 4H, H-3, H-13, H-14, H-15), 7.50 (m, 2H, H-12, H-16), 7.69 (d, 1H, J = 15.9 Hz, H-10). ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 20.3 (4 × CH_3, Ac), 60.7 (CH_2, C6′), 61.6 (CH_2, C-7), 68.0 (CH, C-4′), 70.7 (CH, C-2′), 71.7 (CH, C-3′), 72.3 (CH, C-5′), 99.1 (CH, C-1′), 115.6 (CH, C-2), 117.6 (CH, H-9), 123.3 (CH, C-4), 126.1 (C, C-6), 127.8 (2 × CH, C-12, C-16), 128.6 (2 × CH, C-13, C-15), 129.2 (CH,C-3), 129.8 (CH, C-5), 130.1 (CH, C-14), 134.0 (C, C-11), 144.8 (CH, C-10), 154.2 (C, C-1), 166.3 (C═O, C-8), 169.0, 169.9, 170.2 (4 × C═O, Ac). Anal. Calcd for $C_{30}H_{32}O_{12}$: C, 61.64; H, 5.52. Found: C, 61.48; H, 5.50.

3.5. Acylation of glycoside 2, 3, and 4. General method

To a solution of glycoside **2**,**3**, or **4** (0.2 mmol) in 1 mL $CHCl_3$, 0.22 mmol of acyl chloride and 0.26 mmol of pyridine were added. The reaction mixture was kept at room temperature for 24 h and diluted with 20 mL $CHCl_3$. The solution was washed with 0.1 M H_2SO_4, satd Na_2CO_3, water, dried over Na_2SO_4 and evaporated. The residue was recrystallized from ethanol.

3.5.1. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-benzyl (4-acetoxy) benzoate (7)

The compound **7** was obtained from 4-acetoxy benzoic acid and glycoside **3**. Yield 53%, mp 135–137 °C. UV λ_{max} (EtOH)/nm: 235. IR (KBr, ν_{max}/cm^{-1}): 1740, 1730, 1600, 1370, 1210, 1040, 910, 750. ^{1}H NMR ($CDCl_3$, 300 MHz) δ: 2.03, 2.04, 2.05, 2.07, 2.31 (s, 5 × 3H, Ac), 3.84–3.88 (m, 1H, H-5′), 4.16 (dd, 1H, J = 2.1, 12,3 Hz, H-6′b), 4.25 (dd, 1H, J = 5.1, 12.3 Hz, H-6′a), 5.11 (d, 1H, J = 7.2 Hz H-1′), 5.15 (m, 1H, H-4′), 5.25–5.44 (m, 2H, H-2′, H-3′), 5.30 (m, 2H, H-7), 7.11 (m, 2H, H-2, H-4), 7.16 (d, 2H, J = 8.4 Hz, H-11, H-13), 7.29 (m, 1H, H-3), 7.40 (d, 1H, J = 7.2 Hz, H-5), 8.09 (d, 2H, J = 8.4 Hz, H-10, H-14). ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 20.6, 21.2 (5 × CH_3, Ac), 61.5 (CH_2, C6′), 61.9 (CH_2, C-7), 68.4 (CH, C-4′), 71.1 (CH, C-2′), 72.1 (CH, C-3′), 72.7 (CH, C-5′), 99.4 (CH, C-1′), 116.0 (CH, C-2), 121.7 (2 × CH, C-11, C-13), 123.6 (CH, C-4), 126.4 (C, C-6), 127.7 (C, C-9), 129.3 (C, C-3), 129.4 (C, C-5), 131.3 (2 × CH, C-10, C-14), 154.4 (C, C-1), 154.5 (C, C-12), 165.4 (C═O, C-8), 168.8,

169.4, 170.2, 170.5 (5 × C=O, Ac). Anal. Calcd for $C_{30}H_{32}O_{14}$: C, 58.44; H, 5.23. Found: C, 58.31; H, 5.39.

3.5.2. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-benzyl (3-methoxy-4-acetoxy) benzoate (8)

The compound **8** was obtained from 3-methoxy-4-acetoxy benzoic acid and glycoside **3**. Yield 66%, mp 122–124 °C. UV λ_{max} (EtOH)/nm: 242, 291. IR (KBr, ν_{max}/cm^{-1}): 2950, 1740, 1600, 1370, 1240, 1050, 1040, 910, 750. ^{1}H NMR ($CDCl_3$, 300 MHz) δ: 2.03, 2.05, 2.07, 2.34 (s, 5 × 3H, Ac), 3.88 (m, 1H, H-5′), 3.88 (s, 3H, OCH_3), 4.16 (dd, 1H, J = 2.1, 12,0 Hz, H-6′b), 4.26 (dd, 1H, J = 5.1, 12.3 Hz, H-6′a), 5.09 (d, 1H, J = 7.5 Hz H-1′), 5.14 (m, 1H, H-4′), 5.25–5.44 (m, 2H, H-2′, H-3′), 5.30 (m, 2H, H-7), 7.08 (m, 3H, H-2, H-4, H-13), 7.26 (m, 1H, H-3), 7.39 (d, 1H, J = 6.9 Hz, H-5), 7.68 (s, 1H, H-10), 7.68 (dd, 1H, J = 1.2, 9.0 Hz, H-14). ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 20.6 (5 × CH_3, Ac), 56.2 (OCH_3), 61.6 (CH_2, C6′), 61.9 (CH_2, C-7), 68.3 (CH, C-4′), 71.0 (CH, C-2′), 72.1 (CH, C-3′), 72.7 (CH, C-5′), 99.5 (CH, C-1′), 113.6 (CH, C-10), 115.9 (CH, C-2), 122.7 (CH, C-4), 122.8 (CH, C-13), 123.7 (CH, C-14), 126.4 (CH, C-6), 128.9 (C, C-9), 129.3 (C, C-5), 129.4 (CH, C-3), 143.7 (C, C-12), 151.1 (C, C-11), 154.5 (C, C-1), 165.6 (C=O, C-8), 168.5, 169.3, 169.4, 170.2, 170.6 (5 × C=O, Ac). Anal. Calcd for $C_{31}H_{34}O_{15}$: C, 57.58; H, 5.30. Found: C, 57.40; H, 5.55.

3.5.3. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-5-acetoxy benzyl (3,4-diacetoxy) cinnamoate (9)

The compound **9** was obtained from 3,4-diacetoxy cinnamoyl chloride and glycoside **4**. Yield 85%, mp 131–132 °C. UV λ_{max} (EtOH)/nm: 280. IR (KBr, ν_{max}/cm^{-1}): 1750, 1640, 1500, 1370, 1210, 1030, 905. ^{1}H NMR ($CDCl_3$, 300 MHz) δ: 2.02, 2.03, 2.06, 2.10, 2.27, 2.28, 2.29 (s, 7 × 3H, Ac), 3.82 (m, 1H, H-5′), 4.15 (dd, 1H, J = 9.9, 1.7 Hz, H-6′a), 4.24 (dd, 1H, J = 5.3, 12.0 Hz, H-6′b), 5.02 (m, 1H, H-1′), 5.12 (m, 1H, H-4′), 5.17 (m, 2H, H-7), 5.27 (m, 2H, H-2′, H-3′), 6.39 (d, 1H, J = 15.9 Hz, H-9), 6.97 (dd, 1H, J = 2.5, 8.7 Hz, H-3), 7.09 (d, 1H, J = 7.2 Hz, H-2), 7.10 (s, 1H, H-5), 7.19 (d, 1H, J = 8.4 Hz, H-15), 7.36 (s, 1H, H-12), 7.38 (d, 1H, J = 8.4 Hz, H-16), 7.62 (d, 1H, J = 16.2 Hz, H-10). ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 20.6 (6 × CH_3, Ac), 21.0 (CH_3, Ac), 60.6 (CH_2, C-7), 61.8 (CH_2, C-6′), 68.1 (CH, C-4′), 70.9 (CH, C-2′), 72.0 (CH, C-3′), 72.5 (CH, C-5′), 99.7 (CH, C-1′), 117.1 (CH=CH, C-9), 118.7 (CH, C-2), 122.1 (2 × CH, C-3,C-5), 122.7 (CH, C-15), 123.9 (CH, C-12), 126.5 (CH, C-16), 127.8 (C, C-6), 133.1 (C, C-11), 142.4 (C, C-13), 143.4 (C, C-14), 145.5 (CH=CH, C-10), 146.3 (C, C-4), 151.8 (C, C-1), 166.0 (C=O, C-8), 168.0, 169.3, 169.6, 170.2, 170.5 (7 × C, Ac). HRESIMS Calcd for $[M+Na]^+$ 781.19504. Found $[M+Na]^+$ 781.19502.

3.5.4. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-5-acetoxy benzylcinnamoate (10)

The compound **10** was obtained from cinnamoyl chloride and glycoside **4**. Yield 40%, mp 74–76 °C. UV λ_{max} (EtOH)/nm: 278. IR (KBr, ν_{max}/cm^{-1}): 1750, 1640, 1500, 1370, 1210, 1190, 1030, 905. ^{1}H NMR ($CDCl_3$, 300 MHz) δ: 2.035, 2.04, 2.07, 2.12, 2.28 (s, 5 × 3H, Ac), 3.84 (m, 1H , H-5′), 4.16 (dd, 1H, J = 2.4, 12.3 Hz, H-6′b), 4.25 (dd, 1H, J = 5.4, 12.3 Hz, H-6′a), 5.01 (d, 1H, J = 7.2, Hz, H-1′), 5.15–5.21 (m, 2H, H-4′, H-3′), 5.25 (m, 1H, H-2′), 5.29 (m, 2H, CH_2, H-7), 6.45 (d, 1H, J = 15.9 Hz, H-9), 6.99 (dd, 1H, J = 2.7, 8.7 Hz, H-3), 7.10 (s, 1H, H-5), 7.13 (m, 1H, H-2), 7.37 (m, 3H, H-13, H-14, H-15), 7.52 (m, 2H, H-12,H-16), 7.70 (d, 1H, J = 16.2 Hz, H-10). ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 20.4, 20.9 (5 × CH_3, Ac), 60.3 (CH_2, C6′), 61.6 (CH_2, C-7), 68.0 (CH, C-4′), 70.7 (CH, C-2′), 71.8 (CH, C-3′), 72.4 (CH, C-5′), 99.6 (CH, C-1′), 117.0 (CH, C-2), 117.4 (CH, H-9), 121.9 (2 × CH, C-3, C-5), 127.7 (C, C-6), 127.9 (2 × CH, C-12, C-16), 128.7 (2 × CH, C-13, C-15), 130.2 (CH,C-14), 134.0 (CH, C-11), 145.1 (C, C-4), 146.1 (CH, C-10), 151.6 (CH, C-1), 166.2 (C=O, C-8), 169.1, 169.3, 169.9, 170.3 (5 × C=O, Ac). Anal. Calcd for $C_{32}H_{34}O_{14}$: C, 59.81; H, 5.33. Found: C, 59.76; H, 5.47.

3.5.5. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-5-acetoxy benzyl (4-acetoxy) benzoate (11)

The compound **11** was obtained from 4-acetoxy benzoyl chloride and glycoside **4**. Yield 52%, mp 93–94 °C. UV λ_{max} (EtOH)/nm: 232, 274. IR (KBr, ν_{max}/cm^{-1}): 1750, 1640, 1600, 1500, 1370, 1210, 1190, 1030, 906. ^{1}H NMR ($CDCl_3$, 300 MHz) δ: 2.03, 2.04, 2.07, 2.10, 2.28, 2.32 (s, 6 × 3H, Ac), 3.81–3.86 (m, 1H, H-5′), 4.16 (dd, 1H, J = 2.1, 12,3 Hz, H-6′b), 4.25 (dd, 1H, J = 5.1, 12.3 Hz, H-6′a), 5.02 (d, 1H, J = 7.2 Hz H-1′), 5.14 (m, 1H, H-4′), 5.20–5.41 (m, 2H, H-2′, H-3′), 5.28 (m, 2H, H-7), 7.02 (dd, 1H, J = 2.7, 8.7 Hz, H-3), 7.08. ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 20.5, 21.1 (6 × CH_3, Ac), 60.9 (CH_2, C6′), 61.7 (CH_2, C-7), 68.1 (CH, C-4′), 70.9 (CH, C-2′), 72.0 (CH, C-3′), 72.5 (CH, C-5′), 99.7 (CH, C-1′), 117.1 (CH, C-2), 121.6 (2 × CH, C-11, C-13), 121.8 (CH, C-3), 122.1 (CH, C-5), 127.5 (C, C-9), 127.8 (C, C-6), 131.2 (2 × CH, C-10, C-14), 146.2 (C, C-4), 151.5 (C, C-1), 154.3 (C, C-12), 165.0 (C=O, C-8), 168.7, 169.2, 169.5, 170.1, 170.5 (6 × C=O, Ac). Anal. Calcd for $C_{32}H_{33}O_{16}$: C, 56.97; H, 5.08. Found: C, 56.81; H, 5.01.

3.5.6. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-5-acetoxy benzyl (3-methoxy-4-acetoxy) benzoate (12)

The compound **12** was obtained from 3-methoxy-4-acetoxy benzoyl chloride and glycoside **4**. Yield 70%, mp 156–159 °C. UV λ_{max} (EtOH)/nm: 241, 285. IR (KBr, ν_{max}/cm^{-1}): 1760, 1740, 1610, 1380, 1220, 1050, 910, 760. ^{1}H NMR ($CDCl_3$, 300 MHz) δ: 2.03, 2.05, 2.08, 2.28, 2.33 (s, 6 × 3H, Ac), 3.89 (m, 1H, H-5′), 3.89 (s, 3H, OCH_3), 4.16 (dd, 1H, J = 2.1, 12,3 Hz, H-6′b), 4.25 (dd, 1H, J = 5.1, 12.3 Hz, H-6′a), 5.04 (d, 1H, J = 7.2 Hz H-1′), 5.14 (m, 1H, H-4′), 5.24–5.42 (m, 2H, H-2′, H-3′), 5.29 (m, 2H, H-7), 6.99 (dd, 1H, J = 2.7, 8.7 Hz, H-3), 7.10 (m, 3H, H-2, H-5, H-13), 7.68 (m, 2H, H-10, H-14). ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 20.5, 21.0 (6 × CH_3, Ac), 56.1 (OCH_3), 61.0 (CH_2, C6′), 61.8 (CH_2, C-7), 68.1 (CH, C-4′), 70.9 (CH, C-2′), 72.0 (CH, C-3′), 72.5 (CH, C-5′), 99.7 (CH, C-1′), 113.5 (CH, C-10), 117.0 (CH, C-2), 121.8 (CH, C-3), 122.0 (CH, C-5), 122.6 (CH, C-13), 122.8 (CH, C-14), 127.8 (C, C-9), 128.5 (C, C-6), 144.7 (CH, C-12), 145.2 (C, C-4), 151.0 (C, C-11), 151.8 (C, C-1), 165.30 (C=O, C-8), 168.4, 169.1, 169.2, 169.5, 170.0, 170.4 (6 × C=O, Ac). Anal. Calcd for $C_{33}H_{36}O_{17}$: C, 56.25; H, 5.15. Found: C, 56.12; H, 5.34.

3.5.7. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-5-acetoxy benzyl (3-methoxy-4-acetoxy) cinnamoate (13)

The compound **13** was obtained from 3-metoxy-4-acetoxy cinnamoyl chloride and glycoside **4**. Yield 60%, mp 157–158 °C. UV λ_{max} (EtOH)/nm: 323, 304. IR (KBr, ν_{max}/cm^{-1}): 3970, 1760, 1640, 1605, 1380, 1220, 1190, 1175, 180, 1045, 980, 908, 850, 825, 600. ^{1}H NMR ($CDCl_3$, 300 MHz) δ: 2.02, 2.03, 2.06, 2.10, 2.27, 2.30 (s, 6 × 3H, Ac), 3.84 (m, 1H, H-5′), 3.84 (s, 3H, OCH_3), 4.15 (dd, 1H, J = 10.2, 1.7 Hz, H-6′a), 4.24 (dd, 1H, J = 5.1, 12.3 Hz, H-6′b), 5.02 (d, 1H, J = 7.2 Hz, H-1′), 5.12–5.34 (m, 5H, H-2′, H-3′, H-4′, H-7), 6.39 (d, 1H, J = 16.2 Hz, H-9), 6.97–7.05 (m, 2H, H-2, H-15), 7.09 (m, 4H, H-3, H-5, H-12, H-16), 7.64 (d, 1H, J = 15.9 Hz, H-10). ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 20.6 (5 × CH_3, Ac), 21.0 (CH_3, Ac), 55.8 (CH_3, OCH_3), 60.5 (CH_2, C-7), 61.8 (CH_2, C-6′), 68.1 (CH, C-4′), 70.9 (CH, C-2′), 72.0 (CH, C-3′), 72.5 (CH, C-5′), 99.7 (CH, C-1′), 111.2 (CH, C-12), 117.1 (CH=CH, C-9), 117.7 (CH, C-2), 121.3 (CH, C-16), 122.1 (2 × CH, C-3,C-5), 123.1 (CH, C-15), 127.8 (C, C-6), 133.1 (C, C-11), 141.4 (C, C-14), 144.6 (CH=CH, C-10), 146.2 (C, C-4), 151.3 (C, C-1), 151.8 (C, C-13), 166.2 (C=O, C-8), 168.6, 169.3, 169.5, 170.1 (6 × C, Ac). HRESIMS Calcd for $[M+Na]^+$ 753.20012, Found $[M+Na]^+$ 753.20007.

3.5.8. 2-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-5-benzoyloxy benzylbenzoate (14)

The compound **14** was obtained from benzoyl chloride and glycoside **5**. Yield 77%, mp 134–135 °C. UV λ_{max} (EtOH)/nm: 230, 276,

IR (KBr, ν_{max}/cm^{-1}): 2940, 1720, 1505, 1500, 1380, 1260, 1250, 1195, 1080, 1060, 1000, 915, 900, 810, 700. ^1H NMR ($CDCl_3$, 300 MHz) δ: 2.04, 2.05, 2.08, 2.09 (s, 4 × 3H, Ac), 3,84 (m, 1H, H-5′), 4.17 (d, 1H, J = 10.8, Hz, H-6′a), 4.27 (dd, 1H, J = 5.1, 12.0, Hz, H-6′b), 5.09 (d, 1H, J = 7.2, Hz, H-1′), 5.16 (m, 1H, H-4′), 5.28–5.45 (m, 4H, H-2′, H-3′, H-7), 7.12–7.21 (m, 2H, H-3, H-5), 7.29 (m, 1H, H-2), 7.41–7.58 (m, 5H, H-11, H-12, H-13, H-18, H-20), 7.60–7.65 (m, 1H, H-19), 8.06 (d, 2H, J = 7.5 Hz, H-10,H-14), 8.16 (d, 2H, J = 7.8, Hz, H-17, H-21). ^{13}C NMR (DMSO-d_6, 75 MHz) δ: 20.5 (4 × CH_3, Ac), 60.9 (CH_2, C-6′), 61.8 (CH_2, C-7), 68.2 (CH, C-4′), 70.9 (CH, C-2′), 72.1 (CH, C-3′), 72.6 (CH, C-5′), 99.9 (CH, C-1′), 117.4 (CH, C-2), 122.0 (CH, C-5), 122.3 (CH, C-3), 128.1 (C, C, C-6), 128.4 (2 × CH, C-11, C-13), 128.6 (2 × CH, C-18, C-20), 129.2 (CH, C-9), 129.7 (2 × CH, C-17, C-21), 129,9 (CH, C-10), 130.1 (2 × CH, C-14, C-16), 133.1 (CH, C-12), 133.7 (C, C-19), 146.6 (C, C-4), 151.9 (C, C-1), 165.2 (C═O, C-15), 166.0 (C═O, C-8), 169.3, 170.1, 170,5 (4 × C═O, Ac). Anal. Calcd for $C_{35}H_{34}O_{14}$: C, 61.94; H, 5.05. Found: C, 61.75; H, 5.13.

3.6. Selective acetyl group cleavage. General method

To glycoside (**3**–**12**) (0.15 mmol) in a mixture of 96%-ethanol and $CHCl_3$ in proportion 1.5–0.5 mL was added 0.5 mL 36% HCl. The reaction mixture was stirred and then kept at 30 °C temperature for 8–13 h. After appropriate time (HPLC control), all solvents were evaporated at low temperature using vacuum and residue was subjected to column chromatography applying gradient elution with chloroform and chloroform–ethanol mixture (from ratio 15:1 to 4:1). Analytical samples were purified by recrystallization from ethanol or water.

3.6.1. 2-(β-D-Glucopyranosyloxy)-benzyl (3,4-dihydroxy) cinnamoate (populoside) (15)

Crystallization from acetone gave pale yellow crystals, yield 50%, mp 178–179 °C, lit.[22] 186–188 °C, lit.[7] 169–170 °C, lit.[6,17] 168–169 °C. UV λ_{max} (EtOH)/nm: 311. IR (KBr, ν_{max}/cm^{-1}): 3450, 2920, 1680, 1600, 1370, 1280, 1160, 1090, 1050, 910, 760. ^1H NMR (DMSO-d_6, 300 MHz) δ: 3.17 (m, 1H, H-4′), 3.26–3.47 (DMSO) (m, 3H, H-2′, H-3′, H-5′), 4.48 (m, 1H, H-6′b), 3.68 (d, 1H, J = 11.4 Hz, H-6′a), 4.84 (m, 1H, H-1′), 5.22 (m, 2H, H-7), 6.32 (d, 1H, J = 15.9 Hz, H-9), 6.75 (d, 1H, J = 8.1 Hz, H-15), 7.00 (m, 3H, H-2, H-4, H-12), 7.14 (d, 1H, J = 7.8 Hz, H-16), 7.28 (m, 2H, H-3, H-5), 7.50 (d, 1H, J = 15.9 Hz, H-10). ^{13}C NMR (DMSO-d_6, 75.5 MHz) δ: 60.9 (2 × CH_2, C6′, C-7), 69.8 (CH, C-4′), 73.2 (CH, C-2′), 76.5 (CH, C-3′), 77.1 (CH, C-5′), 101.1 (CH, C-1′), 114.0 (CH, C-12), 114.9 (CH, C-2), 115.0 (CH, C-9), 115.9 (CH, C-15), 121.5 (CH, C-4), 122.0 (CH, C-16), 125.1 (CH, C-6), 125.7 (CH,C-11), 128.2 (CH, C-3), 129.0 (CH, C-5), 145.5 (2 × C, C-10, C-13), 148.2 (C, C-14), 155.1 (C, C-1), 166.4 (C═O, C-8). The data are in agreement with literature.[6,7]

3.6.2. 2-(β-D-Glucopyranosyloxy)-benzylcinnamoate (16)

Crystallization from water gave colorless crystals, yield 40%, mp 110–112 °C. UV λ_{max} (EtOH)/nm: 278. IR (KBr, ν_{max}/cm^{-1}): 3380, 2920, 1700, 1640, 1500, 1240, 1080, 1050, 770, 750. ^1H NMR (DMSO-d_6, 300 MHz) δ: 3.17 (m, 1H, H-4′), 3.26–3.36 (m, 2H, H-2′, H-3′), 3.43–3.50 (m, 2H, H-6′b, H-5′), 3.69 (d, 1H, J = 10.8 Hz, H-6′a), 4.83 (m, 1H, H-1′), 5.30 (m, 2H, H-7), 6.69 (d, 1H, J = 16.2 Hz, H-9), 7.01 (t, 1H, J = 7.5 Hz, H-4), 7.16 (d, 1H, J = 7.8 Hz, H-2), 7.29 (d, 1H, J = 7.2 Hz, H-5), 7.36 (m, 1H, H-3), 7.42 (m, 3H, H-13, H-14, H-15), 7.68 (d, 1H, J = 16.2 Hz, H-10), 7.74 (m, 2H, H-12, H-16). ^{13}C NMR (DMSO-d_6, 75.5 MHz) δ: 60.5 (CH_2, C6′), 60.9 (CH_2, C-7), 69.5 (CH, C-4′), 73.0 (CH, C-2′), 76.3 (CH, C-3′), 76.9 (CH, C-5′), 100.9 (CH, C-1′), 114.8 (CH, C-2), 117.8 (CH, H-9), 121.7 (CH, C-4), 124.9 (C, C-6), 128.3 (2 × CH, C-12, C-16), 128.8 (3 × CH, C-3, C-13, C-15), 129.2 (CH,C-5), 130.5 (CH, C-14), 134.9 (C, C-11), 144.5 (CH, C-10), 155.0 (C, C-1), 166.0 (C═O, C-8). Anal. Calcd for $C_{22}H_{24}O_8$: C, 63.45; H, 5.81. Found: C, 63.37; H, 5.95.

3.6.3. 2-(β-D-Glucopyranosyloxy)-benzyl (4-hydroxy) benzoate (17)

Crystallization from water gave colorless crystals, yield 80%, mp 165–170 °C. UV λ_{max} (EtOH)/nm: 259. IR (KBr, ν_{max}/cm^{-1}): 3420, 1700, 1610, 1460, 1380, 1280, 1240, 1100, 770, 750. ^1H NMR (DMSO-d_6, 300 MHz) δ: 3.18 (m, 1H, H-4′), 3.27–3.48 (DMSO) (m, 4H, H-2′, H-3′, H-5′, H-6′a), 3.68 (m, 1H, H-6′b), 4.86 (m, 1H, H-1′), 5.35 (m, 2H, H-7), 6.84 (d, 2H, J = 8.4 Hz, H-11, H-13), 7.01 (t, 1H, J = 7.2 Hz, H-4), 7.16 (d, 1H, J = 8.1 Hz, H-2), 7.28 (m, 1H, H-3), 7.35 (d, 1H, J = 7.5 Hz, H-5), 7.85 (d, 2H, J = 8.1 Hz, H-10, H-14). ^{13}C NMR (DMSO-d_6, 75.5 MHz) δ: 60.7 (CH_2, C6′), 61.0 (CH2, C-7), 69.7 (CH, C-4′), 73.4 (CH, C-2′), 76.5 (CH, C-3′), 77.1 (CH, C-5′), 101.0 (CH, C-1′), 115.0 (2 × CH, C-11, C-13), 121.7 (CH, C-2), 120.3 (C, C-9), 121.9 (CH, C-4), 125.4 (C, C-6), 128.3 (CH, C-3), 129.1 (CH, C-5), 131.6 (2 × CH, C-10, C-14), 155.0 (C, C-1), 162.0 (C, C-12), 166.5 (C═O, C-8). Anal. Calcd for $C_{20}H_{22}O_9$: C, 59.11; H, 5.46. Found: C, 58.95; H, 5.54.

3.6.4. 2-(β-D-Glucopyranosyloxy)-benzyl 3-methoxy (4-hydroxy) benzoate (18)

Crystallization from water afforded colorless crystals, yield 35%, mp 173–177 °C. UV λ_{max} (EtOH)/nm: 265, 292. IR (KBr, ν_{max}/cm^{-1}): 3470, 3380, 2930, 1700, 1690, 1610, 1510, 1300, 1230, 1090, 760, 750. ^1H NMR (DMSO-d_6, 300 MHz) δ: 3.16 (m, 1H, H-4′), 3.27–3.38 (DMSO) (m, 2H, H-2′, H-3′), 3.43 (m, 2H, H- 5′, H-6′a), 3.68 (d, 1H, J-11.4 Hz, H-6′b), 3.82 (s, 3H, OCH_3), 4.86 (m, 1H, H-1′), 5.37 (m, 2H, CH_2, H-7), 6.86 (d, 1H, J = 8.1 Hz, H-13), 7.01 (t, 1H, J = 7.5 Hz, H-4), 7.16 (d, 1H, J = 8.1 Hz, H-2), 7.29 (m, 1H, H-3), 7.34 (d, 1H, J = 7.5 Hz, H-5), 7.48 (s, 1H, H-10), 7.51 (dd, 1H, J = 1.5, 8.4 Hz, H-14). ^{13}C NMR (DMSO-d_6, 75.5 MHz) δ: 55.7 (OCH_3), 60.8 (CH_2, C6′), 61.1 (CH_2, C-7), 69.7 (CH, C-4′), 73.3 (CH, C-2′), 76.5 (CH, C-3′), 77.2 (CH, C-5′), 101.0 (CH, C-1′), 112.5 (CH, C-10), 115.0 (CH, C-13), 115.1 (CH, C-2), 120.5 (C, C-9), 121.9 (CH, C-4), 123.5 (CH, C-14), 125.2 (CH, C-6), 129.4 (C, C-5), 130.3 (CH, C-3), 145.4 (C, C-11), 151.5 (C, C-12), 155.2 (C, C-1), 165.4 (C═O, C-8). Anal. Calcd for $C_{21}H_{24}O_{10}$: C, 57.80; H, 5.54. Found: C, 57.71; H, 5.70.

3.6.5. 2-(β-D-Glucopyranosyloxy)-5-hydroxy benzyl (3,4-dihydroxy) cinnamoate (19)

Crystallization from acetone gave yellowish crystals, yield 30%, mp 156–158 °C, lit.[6] 157–158 °C. UV λ_{max} (EtOH)/nm: 248, 300, 331. IR (KBr, ν_{max}/cm^{-1}): 3272, 1680, 1610, 1560, 1520, 1460, 1380, 1280, 1210, 1080, 1050, 990, 810. ^1H NMR (DMSO-d_6, 300 MHz) δ: 3.17 (m, 1H, H-4′), 3.26–3.47 (DMSO) (m, 4H, H-2′, H-3′, H-5′, H-6′), 3.66 (m, 1H, H-6′), 4.62 (d, 1H, J = 6.0 Hz, H-1′), 5.22 (m, 2H, H-7), 6.31 (d, 1H, J = 16.2 Hz, H-9), 6.63 (dd, 1H, J = 9.0, 1.5 Hz, H-3), 6.70 (d, 1H, J = 2.7 Hz, H-5), 6.73 (d, 1H, J = 8.1 Hz, H-15), 7.00–7.03 (m, 2H, H-12, H-16), 7.06 (m, 1H, H-2), 7.50 (d, 1H, J = 15.6 Hz, H-10). ^{13}C NMR (DMSO-d_6, 75.5 MHz) δ: 60.8 (CH_2, C-7), 61.0 (CH_2, C-6′), 69.8 (CH, C-4′), 73.4 (CH, C-2′), 76.5 (CH, C-3′), 77.1 (CH, C-5′), 102.8 (CH, C-1′), 113.8 (CH, C-12), 114.0 (CH═CH, C-9), 114.9 (CH, C-3), 115.2 (CH, C-5), 115.9 (CH, C-15), 117.7 (CH, C-2), 121.7 (CH, C-16), 126.5 (CH, C-11), 127.1 (C, C-6), 145.6 (C, C-1, CH═CH, C-10,), 147.9 (CH, C-13), 148.8 (C, C-14), 152.8 (C, C-4), 166.5 (C═O, C-8). The data agree well with those given in Ref. 6.

3.6.6. 2-(β-D-Glucopyranosyloxy)-5-hydroxy benzylcinnamoate (20)

Crystallization from water gave colorless crystals, yield 34%, mp 135–139 °C. UV λ_{max} (EtOH)/nm: 282. IR (KBr, ν_{max}/cm^{-1}): 3425,

2920, 1700, 1635, 1500, 1210, 1080, 770. ^{1}H NMR (DMSO-d_6, 300 MHz) δ: 3.23 (m, 1H, H-4′), 3.30–3.48 (DMSO) (m, 4H, H-2′, H-3′, H-5′, H-6′a), 3.68 (m, 1H, H-6′b), 4.62 (d, 1H, J = 6.3, Hz, H-1′), 5.26 (m, 2H, CH_2, H-7), 6.62–6.75 (m, 3H, H-3, H-5, H-9), 7.00 (d, 1H, J = 9.0 Hz, H-2), 7.43 (m, 3H, H-13, H-14, H-15), 7.68 (d, 1H, J = 16.2 Hz, H-10), 7.74 (m, 2H, H-12, H-16). ^{13}C NMR (DMSO-d_6, 75.5 MHz) δ: 60.7 (CH_2, C6′), 60.9 (CH_2, C-7), 69.8 (CH, C-4′), 73.2 (CH, C-2′), 76.4 (CH, C-3′), 77.0 (CH, C-5′), 102.6 (CH, C-1′), 114.8 (CH, C-3), 115.3 (CH, C-5), 117.4 (CH, C-2), 118.0 (CH, H-9), 126.7 (C, C-6), 128.3 (2 × CH, C-12, C-16), 128.9 (2 × CH, C-13, C-15), 130.5 (CH,C-14), 134.0 (CH, C-11), 144.7 (C, C-1), 147.9 (CH, C-10), 152.1 (CH, C-4), 166.0 (C═O, C-8). Anal. Calcd for $C_{22}H_{24}O_9$: C, 61.11; H, 5.59. Found: C, 61.00; H, 5.65.

3.6.7. 2-(β-D-Glucopyranosyloxy)-5-hydroxy benzyl (4-hydroxy) benzoate (21)

Crystallization from water gave colorless crystals, yield 55 %, mp 140 °C. UV λ_{max} (EtOH)/nm: 257. IR (KBr, ν_{max}/cm^{-1}): 3360, 2930, 1680, 1610, 1495, 1280, 1210, 1070, 770. ^{1}H NMR (DMSO-d_6, 300 MHz) δ: 3.21 (m, 1H, H-4′), 3.30–3.44 (DMSO) (m, 4H, H-2′, H-3′, H- 5′, H-6′a), 3.67 (m, 1H, H-6′b), 4.63 (m, 1H, H-1′), 5.32 (m, 2H, CH_2, H-7), 6.64 (dd, 1H, J = 2.7, 9.3 Hz, H-3), 6.75 (d, 1H, J = 2.4, Hz, H-5), 6.85 (d, 2H, J = 8.4, Hz, H-11, H-13), 7.00 (d, 1H, J = 8.7 Hz, H-2), 7.85 (d, 2H, J = 8.4 Hz, H-10, H-14). ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 61.8 (CH_2, C6′), 61.9 (CH_2, C-7), 69.8 (CH, C-4′), 74.2 (CH, C-2′), 76.5 (CH, C-3′), 77.0 (CH, C-5′), 102.6 (CH, C-1′), 114.2 (CH, C-5), 115.0 (CH, C-3), 115.5 (2 × CH, C-11, C-13), 117.8 (CH, C-2), 120.2 (C, C-9), 127.0 (C, C-6), 131.4 (2 × CH, C-10, C-14), 147.7 (C, C-1), 152.2 (C, C-4), 163.0 (C, C-12), 165.3 (C═O, C-8). Anal. Calcd for $C_{20}H_{22}O_{10}$: C, 56.87; H, 5.25. Found: C, 56.80; H, 5.29.

3.6.8. 2-(β-D-Glucopyranosyloxy)-5-hydroxy benzyl (3-methoxy-4-hydroxy) benzoate (22)

Crystallization from water gave colorless crystals, yield 36 %, mp 128–136 °C. UV λ_{max} (EtOH)/nm: 264, 292. IR (KBr, ν_{max}/cm^{-1}): 2970, 1695, 1520, 1290, 1215, 1080, 1240, 990, 760. ^{1}H NMR (DMSO-d_6, 300 MHz) δ: 3.17 (m, 1H, H-4′), 3.22–3.44 (m, 4H, H-2′, H-3′, H-5′, H-6′a), 3.67 (d, 1H, J-11.4 Hz, H-6′b), 3.82 (s, 3H, OCH_3), 4.63 (m, 1H, H-1′), 5.33 (m, 2H, CH_2, H-7), 6.63 (dd, 1H, J = 2.7, 8.7 Hz, H-3), 6.74 (d, 1H, J = 3.0 Hz, H-5), 6.87 (d, 1H, J = 8.1 Hz, H-13), 7.00 (d, 1H, J = 8.7 Hz, H-2), 7.49 (s, 1H, H-10), 7.54 (dd, 1H, J = 3.0, 8.4 Hz, H-14). ^{13}C NMR (DMSO-d_6, 75.5 MHz) δ: 55.8 (OCH_3), 60.9 (CH_2, C6′), 61.0 (CH_2, C-7), 69.8 (CH, C-4′), 73.4 (CH, C-2′), 76.6 (CH, C-3′), 77.1 (CH, C-5′), 102.6 (CH, C-1′), 112.7 (CH, C-10), 114.2 (CH, C-13), 115.0 (CH, C-5), 115.3 (CH, C-3), 117.7 (CH, C-2), 120.5 (C, C-9), 123.6 (CH, C-14), 127.1 (C, C-6), 147.3 (CH, C-11), 147.8 (C, C-1), 151.7 (C, C-12), 152.4 (C, C-4), 165.5 (C═O, C-8). Anal. Calcd for $C_{21}H_{24}O_{11}$: C, 55.75; H, 5.35. Found: C, 55.71; H, 5.37.

3.6.9. 2-(β-D-Glucopyranosyloxy)-5-hydroxy benzyl (3-methoxy-4-hydroxy) cinnamoate (23)

Crystallization from water gave colorless crystals, yield 48%, mp 99–100 °C. UV λ_{max} (EtOH)/nm: 296, 325. IR (KBr, ν_{max}/cm^{-1}): 3405, 2930, 1690, 1600, 1500, 1270, 1210, 1175, 1075, 1035, 810. ^{1}H NMR (MeOD, 300 MHz) δ.: 3.82 (m, 1H, H-5′), 4.15 (dd, 1H, J = 9.9, 1.7 Hz, H-6′a), 4.24 (dd, 1H, J = 5.3, 12.0 Hz, H-6′b), 5.02 (m, 1H, H-1′), 5.12 (m, 1H, H-4′), 5.17 (m, 2H, H-7), 5.27 (m, 2H, H-2′, H-3′), 6.39 (d, 1H, J = 15.9 Hz, H-9), 6.97 (dd, 1H, J = 2.5, 8.7 Hz, H-3), 7.09 (d, 1H, J = 7.2 Hz, H-2), 7.10 (s, 1H, H-5), 7.19 (d, 1H, J = 8.4 Hz, H-15), 7.36 (s, 1H, H-12), 7.38 (d, 1H, J = 8.4 Hz, H-16), 7.62 (d, 1H, J = 16.2 Hz, H-10). ^{13}C NMR (MeOD, 75.5 MHz) δ: 60.6 (CH_2, C-7), 61.8 (CH_2, C-6′), 68.1 (CH, C-4′), 70.9 (CH, C-2′), 72.0 (CH, C-3′), 72.5 (CH, C-5′), 99.7 (CH, C-1′), 117.1 (CH═CH, C-9), 118.7 (CH, C-2), 122.1 (2 × CH, C-3,C-5), 122.7 (CH, C-15), 123.9 (CH, C-12), 126.5 (CH, C-16), 127.8 (C, C-6), 133.1 (C, C-11), 142.4 (C, C-13), 143.4 (C, C-14), 145.5 (CH═CH, C-10), 146.3 (C, C-1), 151.8 (C, C-4), 166.0 (C═O, C-8). Anal. Calcd for $C_{23}H_{26}O_{11}$: C, 57.74; H, 5.48. Found: C, 57.67; H, 5.53.

3.6.10. 2-(β-D-Glucopyranosyloxy)-5-benzoyloxy benzylbenzoate (24)

Crystallization from water gave colorless crystals, yield 60%, mp 190–194 °C. UV λ_{max} (EtOH)/nm: 230, 276. IR (KBr, ν_{max}/cm^{-1}): 2950, 1730, 1715, 1500, 1390, 1255, 1200, 1080, 1060, 1040, 890, 795 703. ^{1}H NMR (DMSO, 300 MHz) δ.: 3,17 (m, 1H, H-4′), 3.30–3.38 (DMSO) (m, 3H, H-2′, H-3′, H-5′), 3.45–3.52 (m, 1H, H-6′a), 3.69–3.75 (m, 1H, H-6′b), 4.91 (d, 1H, J = 6.6, Hz, H-1′), 5.39 (dd, 2H, J = 13.5, 3.6 , Hz, H-7), 7.27 (m, 2H, H-3, H-5), 7.33 (m, 1H, H-2), 7.50–7.68 (m, 5H, H-11, H-12, H-13, H-18, H-20), 7.72–7.77 (m, 1H, H-19), 8.01 (d, 2H, J = 7.2 Hz, H-10,H-14), 8.11 (d, 2H, J = 6.9, Hz, H-17, H-21). ^{13}C NMR (DMSO, 75.5 MHz) δ: 60.9 (CH_2, C-6′), 61.4 (CH_2, C-7), 69.8 (CH, C-4′), 73.1 (CH, C-2′), 76.5 (CH, C-3′), 76.9 (CH, C-5′), 100.1 (CH, C-1′), 117.4 (CH, C-2), 121.9 (CH, C-5), 122.8 (CH, C-3), 126.1 (C, C, C-6), 129.0 (5 × CH, C-9, C-11, C-13, C-18, C-20), 129.2 (2 × CH, C-17, C-21), 129,5 (CH, C-10), 129.8 (2 × CH, C-14, C-16), 133.2 (CH, C-12), 134.0 (C, C-19), 145.0 (C, C-4), 152.9 (C, C-1), 164.9 (C═O, C-15), 165.8 (C═O, C-8). Anal. Calcd for $C_{27}H_{26}O_{10}$: C, 63.53; H, 5.13. Found: C, 63.60; H, 5.25.

3.7. 4-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyloxy)-phenylbenzoate (26)

The compound **26** was obtained by glycosylation of (**25**), yield, mp 150–151 °C, lit.[25] 136–138 °C, lit.[30] 154–155 °C. UV λ_{max} (EtOH)/nm: 283. IR (KBr, ν_{max}/cm^{-1}): ν/cm^{-1}: 1740, 1505, 1370 1230, 1200, 1065, 700. ^{1}H NMR ($CDCl_3$, 300 MHz) δ.: 2.04, 2.05, 2.08 (s, 4 × 3H, Ac), 3.85 (m, 1H, H-5′), 4.15 (d, 1H, J = 12.3 Hz, H-6′b), 4.27 (dd, 1H, J = 5.4, 12.3 Hz, H-6′a), 5.05 (d, 1H, J = 6.9 Hz, H-1′), 5.15 (m, 1H, H-4′), 5.25–5.34 (m, 2H, H-2′, H-3′), 7.03 (d, 2H, J = 9.0 Hz, H-2, H-6), 7.13 (d, 2H, J = 9.0 Hz, H-3, H-5), 7.48 (m, 2H, H-18, H-20), 7.61 (t, 1H, J = 7.2 Hz, H-19), 8.17 (d, 2H, J = 7.5 Hz, H-17, H-21). ^{13}C NMR ($CDCl_3$, 75.5 MHz) δ: 20.7 (4 × CH_3, $COCH_3$), 62.1 (CH_2, C6′), 68.4 (CH, C-4′), 71.3 (CH, C-2′), 72.2 (CH, C-5′), 72.8 (CH, C-3′), 99.7 (CH, C-1′), 118.2 (2 × CH, C-2, C-6), 122.8 (2 × CH, C-5, C-3), 128.7 (2 × CH, C-18, C-20), 129.5 (C, C-16), 130.3 (2 × CH, C-17,C-21), 133.8 (CH, C-19), 146.6 (C, C-4), 154.7 (C, C-1), 165.0 (C═O, C-15), 169.5, 170.3, 170.7 (4 × C, Ac). The data are in agreement with literature.[25]

3.8. 4-(β-D-Glucopyrfmanosyloxy)-phenylbenzoate (27)

The compound **27** was obtained according to procedure for **14**–**23** from glycoside **25** and was crystallized from water. Yeild 36%, mp 189–196 °C. UV λ_{max} (EtOH)/nm: 230, 269. IR (KBr, ν_{max}/cm^{-1}): ν/cm^{-1}: 3540, 3390, 2890, 1712, 1600, 1510, 1455, 1400, 1275, 1240, 1200, 1080, 1040, 820, 710. ^{1}H NMR (DMSO, 300 MHz) δ: 3.17–3.21 (m, 1H, H-4′), 3.25–3.35 (m, 3H, H-2′, H-3, H-5′), 3.44–3.53 (1H, m, H-6′a), 3.69 (dd, 1H, J = 4.5, 11.1, Hz, H-6′b), 4.87 (d, 1H, J = 6.9, Hz, H-1′), 7.09 (d, 2H, J = 8.7 Hz, H-2, H-6), 7.19 (d, 2H, J = 8.7 Hz, H-3, H-5), 7.58 (m, 2H, H-10, H-12), 7.72 (t, 1H, J = 7.2 Hz, H-11), 8.11 (d, 2H, J = 7.8 Hz, H-9, H-13). ^{13}C NMR (DMSO, 75.5 MHz) δ: 60.6 (CH_2, C6′), 69.6 (CH, C-4′), 73.2 (CH, C-2′), 76.5 (CH, C-5′), 77.0 (CH, C-3′), 100.6 (CH, C-1′), 116.9 (2 × CH, C-2, C-6), 122.6 (2 × CH, C-5, C-3), 129.0 (2 × CH, C-16, C-18, C-20), 129.7 (2 × CH, C-17,C-21), 134.0 (CH, C-19), 144.8 (C, C-4), 155.1 (C, C-1), 165.0 (C═O, C-8). 164.8. Anal. Calcd for $C_{19}H_{20}O_8$: C, 60.63; H, 5.36. Found: C, 60.50; H, 5.52.

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Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.carres.2014.02.014.

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