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Synthesis and antiperoxidant activity of new phenolic *O*-glycosides

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Abstract

We describe the synthesis of some 3-*tert*-butyl-4-hydroxyphenyl D-glycopyranosides by reaction of *tert*-butylhydroquinone with β-D-pentaacetyl-glucose, β-D-pentaacetyl-galactose, 2-acetamido- and 3,4,6-tri-*O*-acetyl-2-butanamido-2-deoxy-β-D-glucopyranosyl chlorides as well as the formation of anomeric 3-*tert*-butyl-4-hydroxyphenyl 4,6-di-*O*-acetyl-2,3-dideoxy-D-*erythro*-hex-2-eno-pyranosides by reaction between *tert*-butylhydroquinone and 3,4,6-tri-*O*-acetyl-D-glucal. All compounds, except 3-*tert*-butyl-4-hydroxyphenyl α- and β-D-glucopyranosides, inhibited lipid peroxidation with a degree of potency comparable to that of *tert*-butyl hydroxyanisole.

Keywords: Antioxidants; *O*-Glycosylated *tert*-butylhydroquinones; Glucals; Inhibition of lipid peroxidation

1. Introduction

It is well established that phenols, in their capacity as hydrogen donors, react with lipid radicals[1] and form stable phenoxy radicals, therefore being effective chain breaking antioxidants.[2] Phenol itself is inactive as an antioxidant, but substitution of alkyl groups into the ortho or para position increases the electron density on the hydroxyl group by an inductive effect and thus increases its reactivity with lipid radicals.[3] *tert*-Butyl hydroxyanisole (BHA) is a synthetic phenolic antioxidant widely used as a stabiliser for fats, oils and lipid-containing foods.[4] Recently, Sgaragli et al.[5] have reported that some hindered phenols like BHA exhibit both antispasmogenic and antioxidant activity. It was proposed that these two potentially useful properties could be combined in properly functionalised phenols and might thus be effective drugs in the prevention of tissue damage from ischemia-reperfusion injury.[6] We previously have synthesised[7] a series of BHA analogues with different water solubility and/or modified antioxidant properties in order to verify their activity either in the extracellular or in the intracellular environment. In the present study *tert*-butylhydroquinone (BHQ) (**1**), selected as a suitable target compound, was *O*-glycosylated with different sugars (D-glucose, D-galactose, D-glucosamine, D-glucal). The difficulties in the preparation of glycosides of a diphenol, such as BHQ, arise

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from the presence of different sites of attack and, as usual for sugar molecules, from the anomerism at C-1. Eventual site- and stereoselectivity of the process is an attractive aspect of the reactions involving this type of molecules.

2. Results and discussion

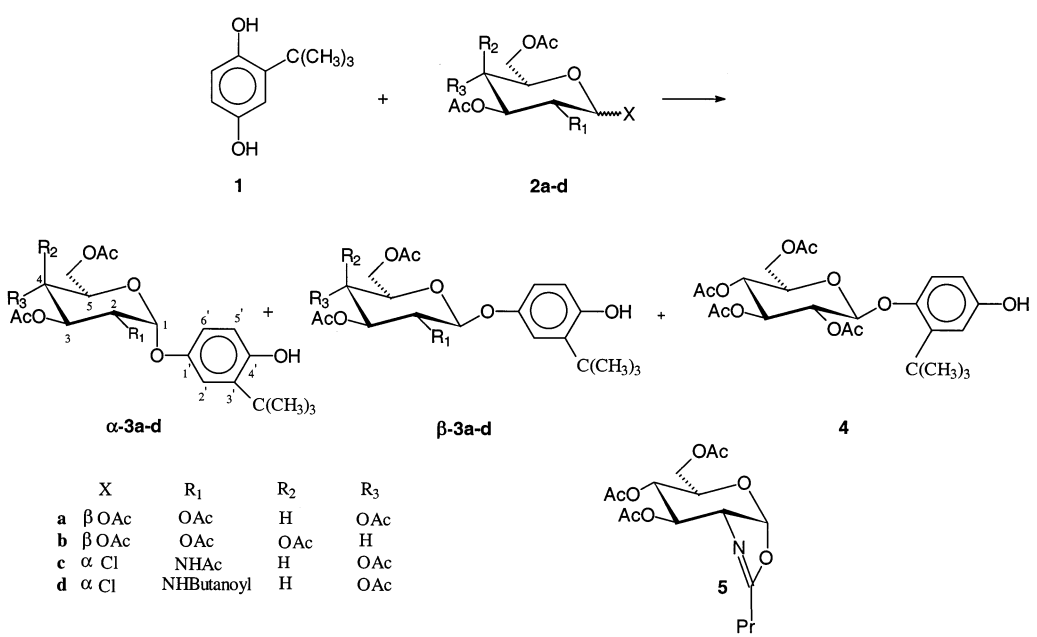
β-D-Glucose pentaacetate (**2a**) reacted with **1** in the presence of *p*-toluenesulfonic acid under Helferich conditions[8] to give a mixture of anomers **3a** in a 33% of combined yield (Table 1). In addition, the glycoside **4** (2%) was isolated from the reaction mixture as a result of glycosylation of **1** at the hindered hydroxy group (Scheme 1). The yield could be improved up to 67% with the formation of **β-3a** anomer almost exclusively (Table 1). The addition of $Yb(OTf)_3$ to the reaction mixture[9] reduced the reaction time, but did not affect the chemical yield and stereoselectivity (Table 1).

The condensation of **1** with β-D-galactose pentaacetate (**2b**) under the modified Helferich conditions afforded the corresponding galactosides **3b** (10:90, α:β ratio) in 40% combined yield (Table 1).

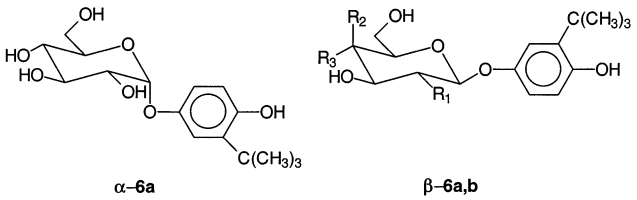
For the synthesis of glucosamine derivatives of BHA, 2-acetamido-2-deoxy-3,4,6-tri-*O*-acetyl-β-D-glucopyranosyl chloride (**2c**) was prepared according to the published procedures[10,11] and reacted in $Zn(Cl)_2$ and dichloromethane.[12] The glycosides **3c** were obtained in 60% yield, with the β anomer as the major product (Table 1).

Table 1
Reaction of *tert*-butylhydroquinone **1** with activated sugars **2a–d**

Donor	Conditions	Products	Combined yield (%)	Ratio α/β
2a	*p*-toluenesulfonic acid, 125 °C	**α-3a/β-3a+4**	33+2	29/71
2a	*p*-toluenesulfonic acid, CH_2Cl_2, reflux	**α-3a/β-3a**	67	4/96
2a	*p*-toluenesulfonic acid, $Yb(OTf)_3$, CH_2Cl_2, reflux	**α-3a/β-3a**	61	10/90
2b	*p*-toluenesulfonic acid, CH_2Cl_2, reflux	**α-3b/β-3b**	40	15/85
2c	$ZnCl_2$, CH_2Cl_2, reflux	**α-3c/β-3c**	60	11/89
2d	$ZnCl_2$, CH_2Cl_2, reflux	**α-3d/β-3d+5**	40+13	5/95



Scheme 1. Synthesis of *O*-glycosides.



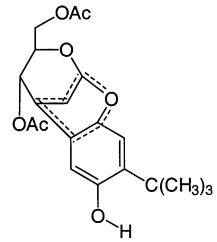
Scheme 2. Deacetylated *O*-glycosides.

A new glycosyl donor, 3,4,6-tri-*O*-acetyl-2-butanamido - 2 - deoxy - β - D - glucopyranosyl chloride (**2d**) was prepared according to the method of Horton.[11] The condensation of **2d** with **1** gave the expected glycosides **3d** (5:95, α:β ratio) in 40% combined yield (Table 1) as well as the oxazoline **5**. This compound was observed in the reaction mixture and identified based on the ^{1}H NMR spectrum of a partially purified fraction, due to its low stability during chromatographic separation.

The high β-selectivity in the glycosylation reactions under acidic conditions is attributed to the neighbouring group effect of the C-2 substituent via formation of an acyloxonium (or oxazolinium) ion. This also results in the blockage of the one face and leads to preferential 1,2-*trans*-glycosylation. Evidence of this mechanistic hypothesis is the isolation of the oxazoline **5**, deriving from the stabilisation of the oxazolinium intermediate by elimination of the proton from the amino group.[13]

Next, the water-soluble analogues of BHA **6** were prepared (Scheme 2) by the deacetylation of the glycosides **3** with sodium methoxide in methanol.[14]

Finally, *tert*-butylhydroquinone (**1**) was *O*-conjugated (Scheme 3) with 3,4,6-tri-*O*-acetyl-D-glucal (**7**), performing the reaction under Ferrier conditions.[15] The condensation afforded an α/β mixture of unsaturated *O*-glycosides **8** as well as the quinone **9**. The unexpected formation of this compound could

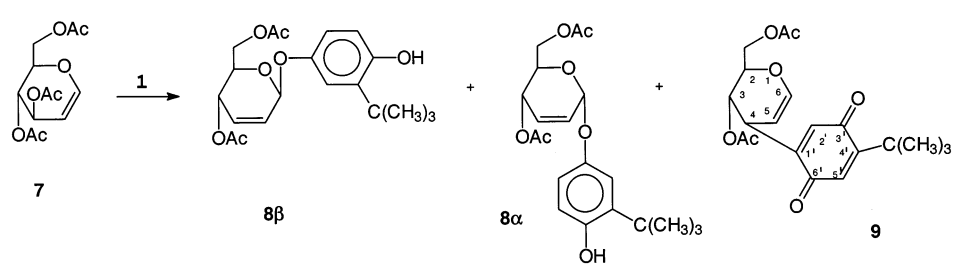


Scheme 4. Possible transition state during the formation of the quinone **9**.

be explained by intramolecular (sigmatropic) rearrangement (Scheme 4) of the product **α-8** and subsequent oxidation to the quinone system.

Structure assignment.—The anomeric configuration of the glycosides **3a**–**d** was determined on the basis of the ^{1}H NMR spectral data (Section 3). As expected, the H-1 signals of β anomers appeared at δ 4.97–5.00 with coupling constants $J_{1,2} = 7.9$ Hz, while the H-1 signals of α anomers were shifted downfield (δ 5.40–5.62) with $J_{1,2} = 3.0$–3.7 Hz. The regioselectivity of the attack on the phenolic groups could be derived from the ^{1}H NMR data of the aromatic moiety, as well as from the observed NOE experiments. Irradiation of H-1 signal in **α-** and **β-3a** showed enhancement of the signals of the aromatic protons in position ortho and para to the *tert*-butyl group, whereas in the case of the glucoside **4**, as NOE effect only the aromatic proton in position ortho to the *tert*-butyl group was observed. Additionally, irradiation of the OH signal gave NOE effect of only one aromatic proton in **α-** and **β-3a**, while NOE effects were observed between OH signal and two aromatic protons for **4**.

The structure of the unsaturated glycosides **8** was assigned on the basis of three signals in the range 6.5–7.0 ppm, with the expected coupling pattern (Section 3), attributable to



Scheme 3. Reaction of *tert*-BHQ with triacetylglucal **7**.

the aromatic protons of the phenolic moiety, (allowing exclusion of a *C*-glycosidic structure for both compounds), the vicinal coupling constant between the H-4 and H-5 protons which is highly diagnostic in assigning the C-1 configuration of 2-unsaturated-*O*-glycosides,[16] ($J_{4,5} = 9.2$ Hz for the α anomer and $J_{4,5} = 3.0$ Hz for the β anomer). In further support was an NOE effect on H-5 detected by irradiation of H-1 of β anomer and in the ^{13}C spectrum of the α anomer the value of heteronuclear ^1J for C-1 (170.9 Hz) were in agreement with an equatorial H-1 (whereas a value near to 160 Hz is expected for an axial conformation of H-1[17]).

Inhibition of lipid peroxides formation.—The compounds in Table 1 were assessed for their capacity to prevent lipid peroxidation in two peroxyl generating systems, as described in Section 3. All compounds were able to inhibit lipid peroxidation, the degree of inhibition being generally greater when it was assessed in the linoleate system. The vehicle Me_2SO exerted no significant effects (data not shown) at the concentration used. As shown in Table 2, **α-8** was the most potent in the linoleate system. **β-3d**, **α-3b**, **β-6b**, **α-3c**, **β-3c**, **α-3a**, **β-3a** and **β-3b** also exhibited remarkable antiperoxidant activity. Whilst, **α-6a** and **β-6a** showed a significantly lower antiperoxidant activity as compared to that of BHA. In the microsome system BHA was the most potent, while **β-6a** was the weakest among the phenols tested (Table 2).

3. Experimental

General.—NMR spectra were recorded on a Bruker AC 200 spectrometer at 200.13 MHz for the ^1H and 50.33 MHz for the ^{13}C nucleus. ^{13}C assignments were established based on chemical shift considerations and $^1H-^{13}C$ 2D-heterocorrelation experiments. MS spectra were recorded on a VG 70 250S instrument in low-resolution mode. TLC was performed on precoated Silica Gel 60 F_{254} plates (E. Merck) with detection by UV light or by spraying with 50% H_2SO_4 in CH_3OH followed by heating at 125 °C. Melting points were determined with a Kofler apparatus and are uncorrected. [α] values were determined on an Optical Activity polarimeter. Column chromatography (CC) was performed on Silica gel (E. Merck, 0.063–0.2 mm). Dichloromethane was distilled from CaH_2 and stored over 4 Å molecu-

Table 2
Rank order of inhibition of peroxides formation by novel antioxidants

Radical generating system–substrate			
ABAP–linoleic acid		Fe^{2+}–ascorbic acid–microsomes	
Compound	IC_{50} (M) [a]	Compound	IC_{50} (M) [a]
α-8	$9.74 \pm 0.45 \times 10^{-8}$ (7.01)	BHA	$3.52 \pm 0.30 \times 10^{-6}$ (5.45)
β-3d	$1.00 \pm 0.13 \times 10^{-7}$ (7.00)	**β-3a**	$4.62 \pm 0.71 \times 10^{-6}$ (5.33)
α-3b	$1.39 \pm 0.13 \times 10^{-7}$ (6.86)	**α-3a**	$8.50 \pm 0.46 \times 10^{-6}$ (5.07)
BHA	$4.28 \pm 0.04 \times 10^{-7}$ (6.37)	**α-8**	$9.73 \pm 0.71 \times 10^{-6}$ (5.01)
α-3c	$6.60 \pm 0.86 \times 10^{-7}$ (6.18)	**β-3b**	$1.33 \pm 0.12 \times 10^{-5}$ (4.88)
β-6b	$6.97 \pm 0.27 \times 10^{-7}$ (6.16)	**α-3b**	$1.37 \pm 0.01 \times 10^{-5}$ (4.86)
β-3c	$9.81 \pm 0.12 \times 10^{-7}$ (6.01)	**β-3d**	$5.04 \pm 0.26 \times 10^{-5}$ (4.30)
α-3a	$9.83 \pm 2.53 \times 10^{-7}$ (6.01)	**α-3c**	$6.61 \pm 0.29 \times 10^{-5}$ (4.18)
β-3a	$1.04 \pm 0.33 \times 10^{-6}$ (5.98)	**β-6b**	$1.03 \pm 0.22 \times 10^{-4}$ (3.99)
β-3b	$1.15 \pm 0.07 \times 10^{-6}$ (5.94)	**α-6a**	$1.52 \pm 0.22 \times 10^{-4}$ (3.82)
α-6a	$7.49 \pm 2.62 \times 10^{-6}$ [b] (5.13)	**β-3c**	$1.66 \pm 0.12 \times 10^{-4}$ (3.78)
β-6a	$9.91 \pm 2.48 \times 10^{-6}$ [b] (5.00)	**β-6a**	$1.26 \pm 0.58 \times 10^{-3}$ [b] (2.90)

[a] Values represent mean ± SEM, $n = 3$–5 (linoleic and microsome preparations). IC_{50} (M) is the molar concentration at which the substance inhibits by 50% the maximal response. Values in brackets represent pIC_{50} (M), the negative $\log_{10}$ of the IC_{50}. Statistical analysis was performed by one-way analysis of variance (ANOVA) followed by Dunnett's test for multiple comparison.
[b] $P < 0.01$, with respect to BHA alone (Dunnet's test).

lar sieves. O_2 consumption was monitored by an O_2 electrode (model 5300 Biological Oxygen monitor, Yellow Spring Instrument Co., Inc. Yellow Spring, OH, USA), equipped with a dual pen recorder.

Preparation of the starting materials.—The starting sugar derivatives **2a**–**c** were prepared according to published procedures[10,11,18] and their spectroscopic data (^{1}H NMR and MS) were in agreement with their structures and, if available, with previously reported values.

*Preparation of 3,4,6-tri-*O*-acetyl-2-butanamido-2-deoxy-α-*D*-glucopyranosyl chloride* (**2d**)[10].—D-Glucosamine hydrochloride (5.39 g) was placed in 80 mL of anhyd MeOH in which 0.56 g of Na was dissolved. Upon gentle swirling, NaCl separated and was removed by filtration. Butanoic anhydride (1.2–1.5 equiv) was added in portions while stirring the solution of D-glucosamine at rt. After crystallisation, the crude 2-butanamido-2-deoxy-D-glucopyranose was removed by filtration, washed with cold MeOH, and dried at rt. Then, 5 g of 2-butanamido-2-deoxy-D-glucopyranose was added in portions to 10 mL of acetyl chloride. After being stirred for 16 h at rt, the reaction mixture was diluted with $CHCl_3$ (40 mL) and poured into 50 mL of ice water. The organic layer was washed with saturated $NaHCO_3$ (40 mL) and dried over $MgSO_4$. Evaporation of the solvent and subsequent crystallisation from dry Et_2O gave **2d** as colourless crystals, mp 144–146 °C; ^{1}H NMR ($CDCl_3$): δ 0.93 (t, 3 H, J 7.1 Hz, CH_3), 1.60 (m, 2 H, CH_2), 2.04, 2.05 and 2.11 (3s, each 3 H, $COCH_3$), 2.20 (m, 2 H, CH_2), 4.10–4.40 (m, 3 H, H-5, H-6a and H-6b), 4.53 (ddd, 1 H, $J_{1,2}$ 3.7, $J_{2,3}$ 9.0 Hz and $J_{2,NH}$ 8.8 Hz, H-2), 5.22 (t, 1 H, $J_{3,4} = J_{4,5}$ 10.0 Hz, H-4), 5.33 (dd, 1 H, H-3), 5.80 (d, 1 H, NH) and 6.19 (d, 1 H, H-1).

Reaction of tert-*butylhydroquinone* (**1**) *and β-*D*-glucose pentaacetate* (**2a**)

With p-*toluenesulfonic acid under Helferich conditions*[8]. A well powdered mixture of **1** (3.2 g, 19 mmol), **2a** (1.17 g, 3 mmol) and *p*-toluenesulfonic acid (0.03 g, 0.18 mmol) in a round-bottom flask was heated at 125 °C for 30 min (oil bath). The reaction was controlled by TLC (2:1, Et_2O–petroleum ether). The mixture was dissolved in CH_2Cl_2 and extracted with 0.5 M aq NaOH to remove the unreacted *tert*-butylhydroquinone. The organic layer was washed with water, dried (Na_2SO_4) and concentrated under reduced pressure. The resulting residue was further separated by CC (1.5:1, Et_2O–petroleum ether) affording the anomers **α-3a** (0.150 g, 10%) and **β-3a** (0.340 g, 23%) as well as the glucoside **4** (0.030 g, 2%).

*3-*tert-*Butyl-4-hydroxyphenyl 2,3,4,6-tetra-*O*-acetyl-α-*D*-glucopyranoside* (**α-3a**): Colourless oil; $[\alpha]_D^{20}$ + 118.24° (*c* 0.3, $CHCl_3$); R_f 0.50 (2:1, Et_2O–petroleum ether); ^{1}H NMR ($CDCl_3$): δ 1.39 (s, 9 H, *tert*-Bu), 2.04, 2.05, 2.06 and 2.07 (4s, each 3 H, 4 Ac), 4.03–4.30 (m, 3 H, H-5, H-6a, H-6b), 5.01 (dd, 1 H, $J_{1,2}$ 3.6, $J_{2,3}$ 10.0 Hz, H-2), 5.15 (t, 1 H, $J_{3,4} = J_{4,5}$ 10.0 Hz, H-4), 5.56 (exch. br s, 1 H, OH), 5.60 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 5.70 (t, 1 H, $J_{2,3} = J_{3,4}$ 10.0 Hz, H-3), 6.59 (d, 1 H, $J_{5',6'}$ 8.5 Hz, H-5′), 6.75 (dd, 1 H, $J_{2',6'}$ 3.1 Hz, H-6′), 6.97 (d, 1 H, H-2′); ^{13}C NMR ($CDCl_3$): δ 20.54, 20.62, 20.63, and 22.53 (4 C, $COCH_3$), 29.32 (3 C, $C(CH_3)_3$), 34.63 (1 C, $C(CH_3)_3$), 61.77 (C-6), 67.72 (C-2), 68.44 (C-3), 70.18 (C-5), 70.61 (C-4), 95.02 (C-1), 114.11, 116.41 and 116.65 (C-2′, 5′ and 6′), 137.70 (C-3′), 149.74 (C-4′), 150.32 (C-1′), 169.72 (2 C, $COCH_3$), 170.29 and 170.76 (2 C, $COCH_3$); MS(EI): m/z (rel. int.) 496 $[M]^+$ (0.8), 331 (22), 169 (79), 151 (13), 127 (22), 109 (57), 43 (100); Anal. Calcd for $C_{24}H_{32}O_{11}$: C, 58.06; H, 6.50. Found: C, 58.45; H, 6.90.

*3-*tert-*Butyl-4-hydroxyphenyl 2,3,4,6-tetra-*O*-acetyl-β-*D*-glucopyranoside* (**β-3a**): Colourless crystals, mp 137–138 °C (hexane–Et_2O); $[\alpha]_D^{20}$ −8.79° (*c* 1.13, $CHCl_3$); R_f 0.40 (2:1, Et_2O–petroleum ether); ^{1}H NMR ($CDCl_3$): δ 1.35 (s, 9 H, *t*-Bu), 2.01, 2.02, 2.05 and 2.06 (4s, each 3 H, 4 Ac), 3.80 (m, 1 H, H-5), 4.15 (dd, 1 H, $J_{5,6a}$ 4.8, $J_{6a,6b}$ 12.3 Hz, H-6a), 4.26 (dd, 1 H, $J_{5,6b}$ 2.3, $J_{6a,6b}$ 12.3 Hz, H-6b), 4.94 (d, 1 H, $J_{1,2}$ 7.3 Hz, H-1), 5.13 (dd, 1 H, $J_{2,3}$ 9.0 Hz, H-2), 5.23 (t, 1 H, $J_{3,4}$ 9.0 Hz, H-3), 5.25 (t, 1 H, $J_{4,5}$ 9.0 Hz, H-4), 6.08 (exch. br s, 1 H, OH), 6.59 (d, 1 H, $J_{5',6'}$ 8.6 Hz, H-5′), 6.67 (dd, 1 H, $J_{2',6'}$ 2.7 Hz, H-6′), 6.90 (d, 1 H, H-2′); ^{13}C NMR ($CDCl_3$): δ 20.50, 20.58, 20.75, and 22.53 (4 C, $COCH_3$), 29.25 (3 C, $C(CH_3)_3$), 34.58 (1 C, $C(CH_3)_3$), 62.07 (C-6), 68.34 (C-2), 71.31 (C-3), 71.85 (C-5), 72.82

(C-4), 100.28 (C-1), 115.32, 116.55 and 116.97 (C-2′, 5′ and 6′), 137.44 (C-3′), 150.28 (C-4′), 150.89 (C-1′), 169.49 (2 C, $COCH_3$), 170.36 and 170.82 (2 C, $COCH_3$); MS(EI): *m/z* (rel. int.) 496 (0.5) $[M]^+$, 331 (30), 169 (100), 151 (23), 127 (28), 109 (70), 43 (81); Anal. Calcd for $C_{24}H_{32}O_{11}$: C, 58.06; H, 6.50. Found: C, 58.06; H, 6.47.

2-tert-*Butyl-4-hydroxyphenyl 2,3,4,6-tetra*-O-*acetyl-β*-D-*glucopyranoside* (**4**): Colourless crystals, mp 233–235 °C (hexane–Et_2O); R_f 0.30 (2:1, Et_2O–petroleum ether); ^1H NMR ($CDCl_3$): δ 1.29 (s, 9 H, *t*-Bu), 1.99, 2.01, 2.03 and 2.05 (4s, each 3 H, 4 Ac), 3.85 (m, 1 H, H-5), 4.10–4.20 (m, 2 H, H-6a and H-6b), 5.15 (d, 1 H, $J_{1,2}$ 7.3 Hz, H-1), 5.16 (dd, 1 H, $J_{2,3}$ 9.0 Hz, H-2), 5.27 (t, 1 H, $J_{3,4}$ 9.0 Hz, H-3), 5.30 (t, 1 H, $J_{4,5}$ 9.0 Hz, H-4), 5.41 (exch. br s, 1 H, OH), 6.60 (dd, 1 H, $J_{3',5'}$ 2.5, $J_{5',6'}$ 8.5 Hz, H-5′), 6.79 (d, 1 H, H-3′), 6.88 (d, 1 H, H-6′); ^{13}C NMR ($CDCl_3$): δ 20.46, 20.53, 20.62 (4 C, $COCH_3$), 29.67 (3 C, $C(CH_3)_3$), 34.63 (1 C, $C(CH_3)_3$), 62.06 (C-6), 68.43 (C-2), 71.31 (C-3), 71.74 (C-5), 73.19 (C-4), 98.03 (C-1), 112.58, 114.49 and 115.43 (C-3′, 5′ and 6′), 140.12 (C-2′), 149.07 (C-4′), 150.98 (C-1′), 169.18, 169.32, 170.36 and 170.82 (4 C, $COCH_3$); MS(EI): *m/z* (rel. int.) 496 (0.2) $[M]^+$, 331 (29), 169 (100), 127 (18), 109 (64); Anal. Calcd for $C_{24}H_{32}O_{11}$: C, 58.06; H, 6.50. Found: C, 58.22; H, 6.72.

With p-*toluenesulfonic acid*. *p*-Toluenesulfonic acid (0.019 g, 0.11 mmol) was added to a solution of **1** (0.199 g, 1.2 mmol) and **2a** (0.390 g, 1 mmol) in CH_2Cl_2 (40 mL). The reaction mixture was refluxed through a column containing molecular sieves 4 Å (10–15 g) for 6 h (TLC control, 1:2, petroleum ether–Et_2O). After cooling, the reaction mixture was diluted with CH_2Cl_2, washed with 0.5 M aq NaOH and water, dried over anhyd Na_2SO_4 and concentrated under reduced pressure. The residue was separated by CC on silica gel (petroleum ether–Et_2O mixture) to give the pure anomers **α-3a** (0.013 g, 3%) and **β-3a** (0.319 g, 64%).

With combined use of p-*toluenesulfonic acid and Yb(OTf)$_3$*. $Yb(OTf)_3$ (0.062 g, 0.1 mmol) was added to a solution of *tert*-butylhydroquinone (**1**) (0.199 g, 1.2 mmol), **2a** (0.390 g, 1 mmol) and *p*-toluenesulfonic acid (0.019 g, 0.11 mmol) in CH_2Cl_2 (40 mL). The reaction mixture was refluxed through a column containing molecular sieves 4 Å (10–15 g) for 3 h (TLC control). The above mentioned work-up procedure and separation by CC afforded the anomers **α-3a** (0.03 g, 6%) and **β-3a** (0.270 g, 55%).

Reaction of tert-*butylhydroquinone* (**1**) *with β*-D-*galactose pentaacetate* (**2b**).—*p*-Toluenesulfonic acid (0.019 g, 0.11 mmol) was added to a solution of **1** (0.199 g, 1.2 mmol) and **2b** (0.390 g, 1 mmol) in CH_2Cl_2 (40 mL). The reaction mixture was carried out as described above (Section 3.4.2, procedure). The crude material was chromatographed (1.5:1, Et_2O–petroleum ether) to give the anomers **α-3b** (0.030 g, 6%) and **β-3b** (0.170 g, 34%).

3-tert-*Butyl-4-hydroxyphenyl 2,3,4,6-tetra*-O-*acetyl-α*-D-*galactopyranoside* (**α-3b**). Colourless oil; $[\alpha]_D^{20}$ +143.94° (*c* 0.66, $CHCl_3$); R_f 0.55 (2:1, Et_2O–petroleum ether); ^1H NMR ($CDCl_3$): δ 1.39 (s, 9 H, *t*-Bu), 1.98, 2.03, 2.09 and 2.17 (4s, each 3 H, 4 Ac), 4.10–4.20 (m, 2 H, H-6a, H-6b), 4.37 (brt, 1 H, $J_{4,5}$ 1.0, $J_{5,6a} = J_{5,6b}$ 6.5 Hz, H-5), 5.27 (dd, 1 H, $J_{2,3}$ 10.0, $J_{3,4}$ 3.6 Hz, H-3), 5.58 (dd, 1 H, $J_{1,2}$ 3.6, Hz, H-2), 5.58 (dd, 1 H, $J_{4,5}$ 1.0 Hz, H-4), 5.65 (d, 1 H, H-1), 6.58 (d, 1 H, $J_{5',6'}$ 8.6 Hz, H-5′), 6.77 (dd, 1 H, $J_{2',6'}$ 2.9 Hz, H-6′), 6.97 (d, 1 H, H-2′). MS(EI): *m/z* (rel. int.) 496 (3) $[M]^+$, 331 (55), 169 (67), 166 (17), 151 (13), 127 (16), 109 (36), 43 (100).); Anal. Calcd for $C_{24}H_{32}O_{11}$: C, 58.06; H, 6.50. Found: C, 58.10; H, 6.63.

3-tert-*Butyl-4-hydroxyphenyl 2,3,4,6-tetra*-O-*acetyl-β*-D-*galactopyranoside* (**β-3b**). Oil; $[\alpha]_D^{20}$ +6.60° (*c* 0.76, $CHCl_3$); R_f 0.43 (2:1, Et_2O–petroleum ether); ^1H NMR ($CDCl_3$): δ 1.39 (s, 9 H, *t*-Bu), 2.02, 2.05, 2.10 and 2.18 (4s, each 3 H, 4 Ac), 4.00–4.20 (m, 3 H, H-5, H-6a and H-6b), 4.92 (d, 1 H, $J_{1,2}$ 7.9 Hz, H-1), 5.10 (dd, 1 H, $J_{2,3}$ 10.4, $J_{3,4}$ 3.4 Hz, H-3), 5.43 (dd, 1 H, H-2), 5.45 (dd, 1 H, $J_{4,5}$ 1.0 Hz, H-4), 6.58 (d, 1 H, $J_{5',6'}$ 8.5 Hz, H-5′), 6.73 (dd, 1 H, $J_{2',6'}$ 2.8, H-6′), 6.96 (d, 1 H, H-2′). MS(EI): *m/z* (rel. int.) 496 (1) $[M]^+$, 331 (50), 169 (55), 166 (13), 151 (11), 127 (13), 109 (30), 43 (100); Anal. Calcd for $C_{24}H_{32}O_{11}.H_2O$: C, 56.03; H, 6.66. Found: C, 55.90; H, 7.05.

Reaction of tert-*butylhydroquinone* (**1**) *with 3,4,6-tri*-O-*acetyl-2-acetamido-2-deoxy*-α-D-*glucopyranosyl chloride* (**2c**) *in the presence of* $ZnCl_2$.—$ZnCl_2$ (0.09 g, 0.6 mmol) was added to a solution of **1** (0.199 g, 1.2 mmol) and **2c** (0.365 g, 1 mmol) in CH_2Cl_2 (40 mL). The reaction mixture was refluxed through a column containing molecular sieves 4 Å (10–15 g) for 6 h (TLC control, 1:1, petroleum ether–EtOAc). After cooling, the reaction mixture was diluted with CH_2Cl_2, washed with 0.5 M aq NaOH and water, dried over anhyd Na_2SO_4 and concentrated under reduced pressure. The residue was chromatographed on silica gel (1:1, petroleum ether–EtOAc) to give the anomers **α-3c** (0.03 g, 6%) and **β-3c** (0.240 g, 54%).

3-tert-*Butyl-4-hydroxyphenyl 2-acetamido-3,4,6-tri*-O-*acetyl-2-deoxy*-α-D-*glucopyranoside* (**α-3c**). Crystals, mp 223–225 °C (hexane–Et_2O); $[\alpha]_D^{20}$ +128.2° (*c* 0.39, $CHCl_3$); R_f 0.24 (1:1, EtOAc–petroleum ether); ^{1}H NMR ($CDCl_3$): δ 1.41 (s, 9 H, *t*-Bu), 1.98 (s, 3 H, NH–Ac), 2.05, 2.06 and 2.07 (3s, each 3 H, 3 Ac), 4.00–4.30 (m, 3 H, H-5, H-6a and H-6b), 4.50 (ddd, 1 H, $J_{1,2}$ 3.0, $J_{2,3}$ 9.5, $J_{2,NH}$ 9.2 Hz, H-2), 5.20 (t, 1 H, $J_{3,4} = J_{4,5}$ 9.5 Hz, H-4), 5.44 (t, 1 H, H-3), 5.45 (d, 1 H, H-1), 5.86 (d, 1 H, $J_{2,NH}$ 9.2 Hz, NH), 6.60 (d, 1 H, $J_{5',6'}$ 8.5 Hz, H-5′), 6.78 (dd, 1 H, $J_{2',6'}$ 3.0, H-6′), 6.96 (d, 1 H, H-2′). MS(EI): *m*/*z* (rel. int.) 495 (0.5) $[M]^+$, 330 (100), 210 (35),168 (73), 150 (83), 127 (13), 43 (87); Anal. Calcd for $C_{24}H_{33}NO_{10}$: C, 58.17; H, 6.71, N, 2.83. Found: C, 57.99; H, 7.00; N, 2.98.

3-tert-*Butyl-4-hydroxyphenyl 2-acetamido-3,4,6-tri*-O-*acetyl-2-deoxy*-β-D-*glucopyranoside* (**β-3c**). Crystals, mp 137–138 °C (hexane–Et_2O); $[\alpha]_D^{20}$ −10.2° (*c* 0.50, $CHCl_3$); R_f 0.14 (1:1, EtOAc–petroleum ether); ^{1}H NMR ($CDCl_3$): δ 1.37 (s, 9 H, *t*-Bu), 1.98 (s, 3 H, NH–Ac), 2.05, 2.06 and 2.07 (3s, each 3 H, 3 Ac), 3.85 (m, 1 H, H-5), 4.00–4.30 (m, 3 H, H-2, H-6a and H-6b), 5.13 (t, 1 H, $J_{3,4} = J_{4,5}$ 10.0 Hz, H-4), 5.17 (d, 1 H, $J_{1,2}$ 8.3 Hz, H-1), 5.41 (t, 1 H, $J_{2,3}$ 10.0 Hz, H-3), 5.75 (d, 1 H, $J_{2,NH}$ 7.7 Hz, NH), 6.58 (d, 1 H, $J_{5',6'}$ 8.5 Hz, H-5′), 6.67 (dd, 1 H, $J_{2',6'}$ 2.7, H-6′), 6.93 (d, 1 H, H-2′); ^{13}C NMR ($CDCl_3$): δ 20.55, 20.61 and 20.65 (3 C, $COCH_3$), 23.14 (1 C, –$NHCOCH_3$), 29.21 (3 C, $C(CH_3)_3$), 34.52 (1 C, $C(CH_3)_3$), 54.73 (1 C, C-2), 62.16 (1 C, C-6), 63.23 (1 C, C-4), 68.45 (1 C, C-5), 71.72 (1 C, C-3), 99.83 (1 C, C-1), 114.93, 116.45 and 116.83 (3 C, ar), 137.26 (1 C, ar*C*–$C(CH_3)_3$), 150.35 and 150.46 (2C, ar–O), 169.41 (1 C, NH*C*O), 170.62, 170.76 and 170.84 (3 C, *C*O); MS(EI): *m*/*z* (rel. int.) 495 (3) $[M]^+$, 330 (71), 210 (34),168 (60), 166 (43), 150 (77), 43 (100); Anal. Calcd for $C_{24}H_{33}NO_{10}$: C, 58.17; H, 6.71; N, 2.83. Found: C, 58.38; H, 6.85; N, 2.75.

Reaction of tert-*butylhydroquinone* (**1**) *with 2-butanamido-3,4,6-tri*-O-*acetyl-2-deoxy*-α-D-*glucopyranosyl chloride* (**2d**) *in the presence of* $ZnCl_2$.—To a solution of **1** (0.199 g, 1.2 mmol) and **2d** (0.394 g, 1 mmol) in CH_2Cl_2 (40 mL) $ZnCl_2$ (0.09 g, 0.6 mmol) was added. The reaction mixture was refluxed through a column containing molecular sieves 4 Å (10–15 g) for 6 h (TLC control, 1:1, petroleum ether–EtOAc). After cooling, the reaction mixture was diluted with CH_2Cl_2, washed with 0.5 M aq NaOH and water, dried over anhyd Na_2SO_4 and concentrated under reduced pressure. The residue was chromatographed on silica gel with 1:1, petroleum ether–EtOAc to give the anomers **α-3d** (0.01 g, 2%) and **β-3d** (0.200 g, 38%) as well as the oxazoline **5** (0.045 g, 13%) contaminated for a small amount of both previous compounds.

3-tert-*Butyl-4-hydroxyphenyl 2-butanamido-3,4,6-tri*-O-*acetyl-2-deoxy*-α-D-*glucopyranoside* (**α-3d**). Oil, $[\alpha]_D^{20}$ +66.67° (*c* 0.15, $CHCl_3$); R_f 0.46 (1:1, EtOAc–petroleum ether); ^{1}H NMR ($CDCl_3$): δ 0.87 (t, 3 H, *J* 7.3 Hz, CH_3), 1.36 (s, 9 H, $C(CH_3)_3$), 1.60 (m, 2 H, CH_2), 2.02 (s, 9 H, $3 \times COCH_3$), 2.20 (m, 2 H, CH_2), 4.00–4.20 (m, 3 H, H-5, H-6a and H-6b), 4.47 (ddd, 1 H, $J_{1,2}$ 3.7, $J_{2,3}$ 10.0, $J_{2,NH}$ 9.3 Hz, H-2), 5.18 (t, 1 H, $J_{3,4} = J_{4,5}$ 10.0 Hz, H-4), 5.40 (t, 1 H, H-3), 5.41 (d, 1 H, H-1), 5.85 (d, 1 H, NH), 6.58 (d, 1 H, $J_{5',6'}$ 8.5 Hz, H-5′), 6.72 (dd, 1 H, $J_{2',6'}$ 2.8 Hz, H-6′), 6.91 (d, 1 H, H-2′); MS(EI) *m*/*z* (rel. int.) 523 $[M]^+$ (1.5), 403 (2.8), 386 (2.5), 358 (70), 298 (9), 256 (8), 238 (33), 196 (33), 178 (68), 166 (37), 151 (24), 126 (33), 108 (36), 71 (45), 43 (100); Anal. Calcd for $C_{26}H_{37}NO_{10}$: C, 59.64; H, 7.12; N, 2.68.Found: C, 59.41; H, 7.39; N, 2.92.

2-Propyl-4,5-dihydro-(3,4,6-tri-O-*acetyl-1,2-dideoxy*-D-*glucopyranoso)-[2,1-d]-1,3-oxazole* (**5**). Oil, R_f 0.40 (1:1, EtOAc–petroleum ether); ^{1}H NMR ($CDCl_3$): δ 0.98 (t, 3 H, J 7.3 Hz, CH_3), 1.68 (sxt, 2 H, J 7.3 Hz, CH_2), 2.32 (t, 2 H, CH_2), 2.04, 2.06 and 2.07 (3s, 9 H, $3 \times COCH_3$), 3.52–3.61 (m, 1 H, H-5), 4.10–4.21 (m, 3 H, H-2, H-6a and H-6b), 4.87 (dt, 1 H, $J_{2,4} = J_{3,4}$ 2.0, $J_{4,5}$ 9.1 Hz, H-4), 5.25 (t, 1 H, $J_{2,3}$ 2.0 Hz, H-3) and 5.93 (d, 1 H, $J_{1,2}$ 7.4, H-1).

3-tert-*Butyl-4-hydroxyphenyl 3,4,6-tri*-O-*acetyl-2-butanamido-2-deoxy-β*-D-*glucopyranoside* (**β-3d**). Crystals, mp 168–170 °C (EtOAc–petroleum ether); $[\alpha]_D^{20}$ −5.05° (*c* 0.99, $CHCl_3$); R_f 0.26 (1:1, EtOAc–petroleum ether); ^{1}H NMR ($CDCl_3$): δ 0.87 (t, 3 H, J 7.3 Hz, CH_3), 1.34 (s, 9 H, $C(CH_3)_3$), 1.60 (m, 2 H, CH_2), 2.01 (s, 6 H, $2 \times COCH_3$), 2.05 (s, 3 H, $COCH_3$), 2.20 (m, 2 H, CH_2), 3.80 (m, 1 H, H-5), 4.10–4.25 (m, 3 H, H-2, H-6a and H-6b), 5.12 (t, 1 H, $J_{3,4} = J_{4,5}$ 10.0 Hz, H-4), 5.13 (d, 1 H, $J_{1,2}$ 8.7 Hz, H-1), 5.40 (t, 1 H, $J_{2,3}$ 10.0 Hz, H-3), 5.63 (d, 1 H, NH), 6.64 (d, 1 H, $J_{5',6'}$ 8.5 Hz, H-5′), 6.65 (dd, 1 H, $J_{2',6'}$ 2.8 Hz, H-6′), 6.89 (d, 1 H, H-2′); MS(EI): *m*/*z* (rel. int.) 523 $[M]^+$ (0.4), 403 (0.3), 386 (1), 358 (20), 238 (5), 196 (27), 178 (59), 166 (23), 151 (21), 126 (25), 108 (28), 71 (34), 43 (100); Anal. Calcd for $C_{26}H_{37}NO_{10}$: C, 59.64; H, 7.12; N, 2.68. Found: C, 59.38; H, 7.49; N, 2.52.

Typical deacetylation procedure.—A 0.2 M solution of methanolic NaOMe (7.6 mL) was added to a solution of glycosides **β-3a**,**b** and **α-3a** (0.25 mmol) in MeOH (10 mL). The solution was stirred at rt for 1–2 h (TLC control), and then Amberlyst (H^+) resin was added until the pH was neutral. The resin was filtered off, washed with MeOH, and the combined solvent was evaporated under reduced pressure. Further purification by CC (5:1 and 4:1, $CHCl_3$–MeOH) afforded the compounds **β-6a**,**b** and **α-6a** in 80–95% yields.

3-tert-*Butyl-4-hydroxyphenyl*α-D-*glucopyranoside* (**α-6a** from **α-3a**). Oil, $[\alpha]_D^{20}$ +134.45° (*c* 0.6, CH_3OH), R_f 0.34 (4:1, $CHCl_3$–MeOH), ^{1}H NMR (CD_3CN): δ 1.40 (s, 9 H, $C(CH_3)_3$), 3.50–3.80 (m, 6 H, H-2, H-3, H-4, H-5, H-6a and H-6b), 5.33 (d, 1 H, $J_{1,2}$ 3.0 Hz, H-1), 6.73 (d, 1 H, $J_{5',6'}$ 8.6 Hz, H-5′), 6.88 (dd, 1 H, $J_{2',6'}$ 2.8 Hz, H-6′), 7.04 (d, 1 H, H-2′), 7.00 (s, 1 H, OH); FABMS *m*/*z* 351 $[M + Na]^+$ (10), 328 (5), 191, 166, 149, 73 (100), 57. Anal. Calcd for $C_{16}H_{24}O_7 \cdot H_2O$: C, 55.48; H, 7.57. Found: C, 55.33; H, 7.37.

3-tert-*Butyl-4-hydroxyphenyl*β-D-*glucopyranoside* (**β-6a** from **β-3a**). Oil, $[\alpha]_D^{20}$ −53.13° (*c* 1.6, CH_3OH), R_f 0.38 (4:1, $CHCl_3$–MeOH), ^{1}H NMR (CD_3CN): δ 1.40 (s, 9 H, $C(CH_3)_3$), 3.40–3.60 (m, 4 H, H-2, H-3, H-4, H-5), 3.85 (m, 2 H, H-6a and H-6b), 4.82 (d, 1 H, $J_{1,2}$ 7.1 Hz, H-1), 6.73 (d, 1 H, $J_{5',6'}$ 8.6 Hz, H-5′), 6.82 (dd, 1 H, $J_{2',6'}$ 2.8 Hz, H-6′), 7.02 (d, 1 H, H-2′), 7.11 (s, 1 H, OH). ^{13}C NMR (CD_3OD): δ 20.50, 20.58, 20.75, and 22.53 (4 C, $COCH_3$), 29.83 (3 C, $C(CH_3)_3$), 35.43 (1 C, $C(CH_3)_3$), 62.38 (C-6), 71.21 (C-2), 74.71 (C-3), 74.85 (C-5), 77.71 (C-4), 103.47 (C-1), 115.82, 117.19 and 117.33 (C-2′, 5′ and 6′), 138.00 (C-3′), 151.72 (C-4′), 152.43 (C-1′); FABMS *m*/*z* 351 $[M + Na]^+$ (3), 328 (5), 325, 191, 166 (100), 149, 73, 57. Anal. Calcd for $C_{16}H_{24}O_7 \cdot H_2O$: C, 55.48; H, 7.57. Found: C, 55.35; H, 7.25.

3-tert-*Butyl-4-hydroxyphenyl* β-D-*galactopyranoside* (**β-6b** from **β-3b**). $[\alpha]_D^{20}$ −20.0° (*c* 1.0, CH_3OH), R_f 0.32 (4:1, $CHCl_3$–MeOH) ^{1}H NMR (Me_2SO): δ 1.32 (s, 9 H, $C(CH_3)_3$), 3.40–3.80 (m, 6 H, H-2, H-3, H-4, H-5, H-6a and H-6b), 4.58 (d, 1 H, $J_{1,2}$ 7.1 Hz, H-1), 6.64 (d, 1 H, $J_{5',6'}$ 8.6 Hz, H-5′), 6.68 (dd, 1 H, $J_{2',6'}$ 2.4 Hz, H-6′), 6.83 (d, 1 H, H-2′). Anal. Calcd for $C_{16}H_{24}O_7 \cdot 1.5H_2O$: C, 54.07; H, 7.66. Found: C, 54.21; H, 7.73.

Reaction of tert-*butylhydroquinone* (**1**) *with 3,4,6-tri*-O-*acetyl*-D-*glucal* (**7**).—*tert*-Butylhydroquinone (0.5 g, 3 mmol) and glucal **7** (0.272 g, 1 mmol) were refluxed in chlorobenzene (4 mL) for 18 h. After removing the solvent, CH_2Cl_2 (10 mL) was added and the mixture was washed with saturated $NaHCO_3$, dried over anhyd Na_2SO_4 and concentrated under reduced pressure. The residue was chromatographed on silica gel with a petroleum ether–Et_2O mixture to give the glycosides **α-8** (60 mg, 15.8%), mixture of **α-8** and **β-8** (150 mg, ratio 1:2, 39.7%), and **9** (80 mg, 21%).

3-tert-*Butyl-4-hydroxyphenyl 4,6-di*-O-*acetyl-2,3-dideoxy*-α-D-erythro-*hex-2-enopyranoside* (**α-8**). Oil, $[\alpha]_D^{20}$ +106.84° (*c* 0.47,

$CHCl_3$); R_f 0.45 (1:1, petroleum ether–Et_2O); ^1H NMR ($CDCl_3$): δ 1.39 (s, 9 H, $C(CH_3)_3$), 2.03 and 2.12 (2s, 6 H, 2 $COCH_3$), 4.10–4.40 (m, 3 H, H-5, H-6a and H-6b), 5.39 (brd, $J_{4,5}$ 9.2 Hz, H-4), 5.56 (brs, 1 H, H-1), 6.01 (brs, 2 H, AB-system, H-2 and H-3), 6.59 (d, 1 H, $J_{5',6'}$ 8.5 Hz, H-5′), 6.85 (dd, $J_{2',6'}$ 2.5 Hz, H-6′), 6.99 (d, H-2′); ^{13}C NMR ($CDCl_3$): δ 20.74 and 20.94 (2 C, $COCH_3$), 29.43 (3 C, $C(CH_3)_3$), 34.63 (1 C, $C(CH_3)_3$), 62.84 (1 C, C-6), 65.15 (1 C, C-4), 67.54 (1 C, C-5), 94.06 (1 C, C-1), 114.95 (1 C, C-6′), 116.68 (1 C, C-5′), 117.15 (1 C, C-2′), 127.35 (1 C, C-3), 129.78 (1 C, C-2), 137.10 (1 C, C-3′), 149.93 (1 C, C-4′), 150.79 (1 C, C-1′), 170.49, 171.10 (2 C, CO); MS EI *m/z*: 378 $[M]^+$ (2), 213 (28), 166 (5), 153 (32), 111 (90), 81 (9), 43 (100). Anal. Calcd for $C_{20}H_{26}O_7$: C, 63.48; H, 6.93. Found: C, 63.22; H, 7.12.

3-tert-*Butyl-4-hydroxyphenyl 4,6-di*-O-*acetyl-2,3-dideoxy-β*-D-erythro-*hex-2-enopyranoside* (**β-8**). Detected in the ^1H NMR spectrum of the mixture; ^1H NMR ($CDCl_3$): δ 1.39 (s, 9 H, $C(CH_3)_3$), 1.93 and 2.11 (2s, 6 H, 2 $COCH_3$), 4.10–4.40 (m, 3 H, H-5, H-6a and H-6b), 5.19 (t, $J_{3,4} = J_{4,5}$ 3.0 Hz, H-4), 5.69 (brd, 1 H, H-1), 6.12 (brs, 2 H, AB-system, H-2 and H-3), 6.56 (d, 1 H, $J_{5',6'}$ 8.5 Hz, H-5′), 6.85 (dd, $J_{2',6'}$ 2.5 Hz, H-6′), 6.99 (d, H-2′).

*(3*S,*4*S,*2*R*)-4-[4-(*tert-*Butyl)-3,6-dioxo-1,4-cyclohexadienyl]-3-methylcarbonyl oxy-3,4-dihydro-2*H-*2-oxinylmethyl acetate* (**9**). oil, $[\alpha]_D^{20}$ −58.33° (*c* 0.60, $CHCl_3$); R_f 0.76 (1:1, petroleum ether–Et_2O); ^1H NMR ($CDCl_3$): δ 1.28 (s, 9 H, $C(CH_3)_3$), 2.00 and 2.08 (2s, 6 H, 2 × $COCH_3$), 3.82 (dt, 1 H, $J_{4,5} = J_{4,6}$ 2.2, $J_{3,4}$ 8.3 Hz, H-4), 4.10 (m, 1 H, H-2), 4.20 (dd, 1 H, $J_{2,7a}$ 2.3, $J_{7a,7b}$ 12.3 Hz, H-7a), 4.38 (dd, 1 H, $J_{2,7b}$ 4.5 Hz, H-7b), 4.54 (dd, $J_{5,6}$ 6.0 Hz, H-5), 5.00 (dd, $J_{2,3}$ 9.7 Hz, H-3), 6.56 (s, 1 H, H-2′), 6.57 (dd, 1 H, H-6), 6.61 (s, 1 H, H-5′). ^{13}C NMR ($CDCl_3$): δ 20.73 (2 C, $COCH_3$), 29.12 (3 C, $C(CH_3)_3$), 35.08 (1 C, $C(CH_3)_3$), 37.01 (1 C, C-4), 61.91 (1 C, C-7), 69.19 (1 C, C-3), 74.81 (1 C, C-2), 100.93 (1 C, C-5), 131.62 (1 C, C-2′), 135.02 (1 C, C-6), 144.86 (1 C, C-5′), 147.24 (1 C, C-4′), 155.95 (1 C, C-1′), 169.86 and 170.67 (2 C, $COCH_3$), 187.60 (2 C, CO); MS E *m/z*: 376 $[M]^+$ (0.9), 316 (5), 256 (40), 243 (100), 227 (5), 43 (55). Anal. Calcd for $C_{20}H_{24}O_7$; C, 63.82; H, 6.42. Found: C, 64.11; H, 6.35.

Inhibition of lipid peroxides formation.— This test was performed by using two model systems, as already described.[2] The first was based on the oxidation of linoleic acid initiated by 2,2′-azobis-2-amidinopropane hydrochloride (ABAP), a thermolabile azo compound which, on decomposition, forms radicals that abstract hydrogen atoms from linoleic acid.

ABAP (11 mM) was added to a suspension of linoleic acid (33 mM) in 50 mM Na–phosphate buffer pH 7.4, in the chamber of an O_2 electrode thermostatted at 37 °C. O_2 consumption was monitored for approximately 6 min before adding the antioxidant at different concentrations. O_2 consumption due to ABAP decomposition was determined separately and subtracted from the peroxidation rate of linoleic acid. In the second system, peroxidation of rat liver microsomes initiated by addition of peroxidising mixture of Fe^{2+}/Fe^{3+}–ascorbic acid 30 mM, was measured as O_2 consumption at 29 °C. Reaction mixtures, in a final volume of 3 mL, contained 0.5 mg microsomal protein, 14.7 mM Me_2SO as vehicle and 20 mM KH_2PO_4–KOH buffer, pH 6.0.

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