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# Tannins and Related Compounds. X.[1] Rhubarb (2): Isolation and Structures of a Glycerol Gallate, Gallic Acid Glucoside Gallates, Galloylglucoses and Isolindleyin

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Six tannin-related compounds (I—VI) have been isolated from commercial rhubarb, and their structures have been established on the basis of chemical and spectroscopic data to be 1-*O*-galloylglycerol (I), gallic acid 3-*O*-β-D-(6′-*O*-galloyl)-glucopyranoside (II), gallic acid 4-*O*-β-D-(6′-*O*-galloyl)-glucopyranoside (III), 1,6-di-*O*-galloyl-β-D-glucose (IV), 6-*O*-galloylglucose (V) and 4-(4′-hydroxyphenyl)-2-butanone 4′-*O*-β-D-(2″-*O*-galloyl)-glucopyranoside (VI, named isolindleyin).

**Keywords**——rhubarb; Polygonaceae; glycerol gallate; gallic acid glucoside gallate; galloylglucose; isolindleyin; tannin-related compound

In a previous paper,[2] the isolation and structure elucidation of the polymeric procyanidin gallates designated as rhatannins, which cause a remarkable decrease of urea-nitrogen concentration (BUN) in rat serum, and of tannin-related compounds such as 3,3′-di-*O*-galloylprocyanidin B-2, 3-*O*-galloylprocyanidin B-1 and 1,2,6-tri-*O*-galloyl-β-D-glucose from commercial rhubarb (Rhei Rhizoma) were reported. In addition, the occurrence of lindleyin (VII), the gallate of *p*-hydroxyphenylbutanone glucoside, which possesses analgesic and anti-inflammatory activities almost equal to those of aspirin and phenylbutanone, was demonstrated. In continuing the chemical examination of tannins and related compounds in rhubarb, we have isolated a glycerol gallate (I), gallic acid glucoside gallates (II and III), galloylglucoses (IV and V) and a *p*-hydroxyphenylbutanone glucoside gallate named isolindleyin (VI) from the aqueous acetone extracts of rhubarb. We now wish to describe the isolation and characterization of these compounds.

The isolation of compounds I—VI from the water-soluble portion of the aqueous acetone extracts was achieved by repeated chromatography on Sephadex LH-20 using a variety of solvent systems (Chart 1). It should be noted in connection with the isolation procedures that most of the anthraquinones found in each fraction were removed by Sephadex LH-20 chromatography using EtOH as an eluent.

Compound I (I), colorless prisms, mp 188—190°C, $[\alpha]_D$ +3.1° (MeOH), $C_{10}H_{12}O_7$, shows a blue coloration with $FeCl_3$ reagent. The field desorption mass spectrum (FD-MS) of I exhibits an intense molecular ion peak at *m/z* 244, together with a minor peak at *m/z* 153 suggestive of the presence of a galloyl group. The $^{13}$C-nuclear magnetic resonance ($^{13}$C-NMR) spectrum shows the presence of one methine and two methylene carbons with an oxygen function [δ 70.7(d), 66.5(t), 63.7(t)]. The occurrence of a galloyl group in I is shown by the signals of six aromatic carbons [δ 109.2(2C), 121.3, 139.0, 146.0(2C)] and an ester carbonyl carbon (δ 167.5). These observations suggest that I is a glycerol monogallate, and that the galloyl group is attached to the primary alcoholic hydroxyl of glycerol, since an unsymmetrical signal pattern of the glycerol moiety is seen in the $^{13}$C-NMR spectrum.

To confirm the structure of I, 1-*O*-galloylglycerol was prepared by partial galloylation of glycerol in the presence of *p*-toluenesulfonic acid. The synthetic sample thus obtained was identical with I in respect of the $^{13}$C-NMR and $^{1}$H-nuclear magnetic resonance ($^{1}$H-NMR) spectra. However, I is optically active, and the absolute configuration of the glycerol methine

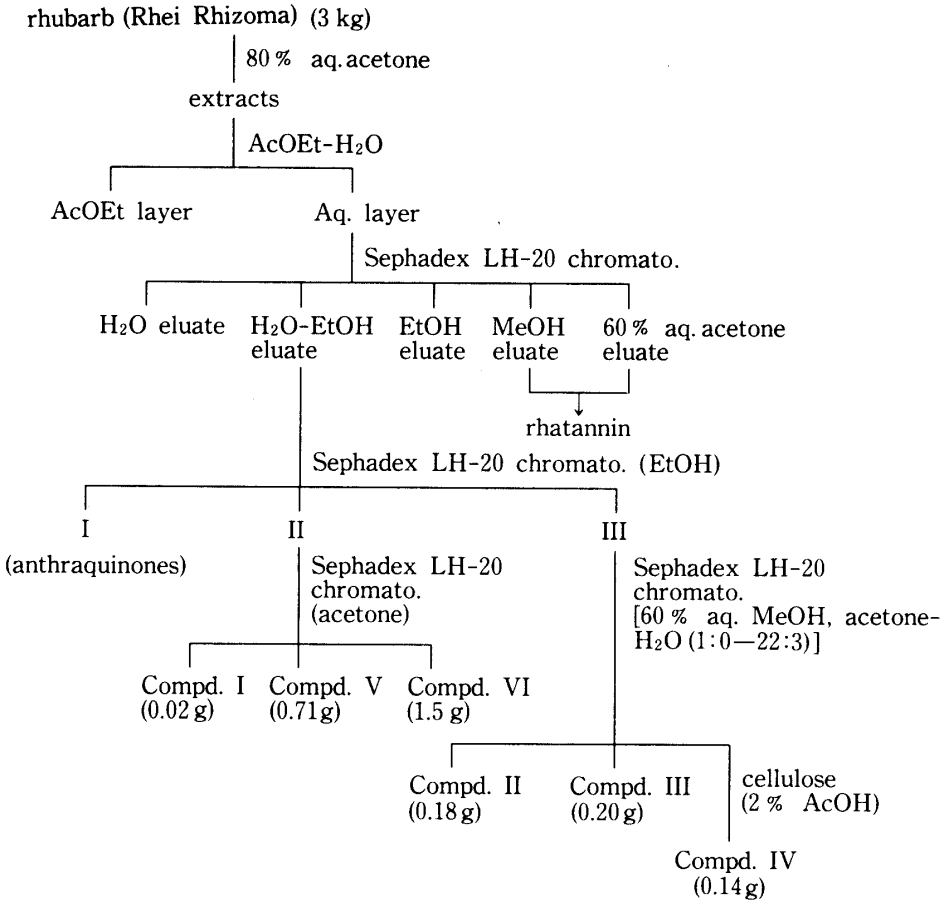



Chart 1

carbon still remains to be determined.

Compound II (II), a white amorphous powder, $[\alpha]_D$ −23.4° (acetone), $C_{20}H_{20}O_{14}\cdot 1/2H_2O$, strongly positive to the $FeCl_3$ reagent (a dark blue color), has a glycosidic nature as revealed by the anomeric signal in the $^1$H- and $^{13}$C-NMR spectra ($\delta$ 5.04, d, $J$=7 Hz; $\delta$ 103.5). The presence of a galloyl group in II is shown by $^{13}$C-NMR signals analogous to those found in I. Acid hydrolysis of II afforded gallic acid and glucose. However, on enzymatic hydrolysis with tannase, which is a sort of esterase, II yielded gallic acid and an amorphous glucoside (IIa), $[\alpha]_D$ −54.2° (MeOH), $C_{13}H_{16}O_{10}\cdot 3/2H_2O$. The $^1$H-NMR spectrum of IIa exhibits, besides sugar signals, two *meta*-coupled aromatic signals ($\delta$ 7.28, 7.41, $J$=2 Hz) which can be assigned to the protons of the gallic acid residue. These chemical and spectroscopic data indicate that II is a gallate of gallic acid 3-*O*-glucoside.

The location of the galloyl group was established to be the $C_6$-position of the glucose moiety by comparison of the $^1$H-NMR spectra of II and IIa; in the $^1$H-NMR spectrum of II two-proton signals having a large coupling constant ($\delta$ 4.25, 4.78, $J_{gem}$=12 Hz), assignable to the $C_6$-methylene protons in the glucose moiety, are shifted downfield as compared with those of IIa. The above conclusion was also supported by the appearance of the deshielded $C_6$-carbon signal ($\delta$ 65.1) in the $^{13}$C-NMR spectrum of II.

The configuration of the anomeric center in the glucose moiety was assigned as $\beta$ from its coupling constant ($J$=7 Hz) in the $^1$H-NMR spectrum. Thus, compound II was characterized as gallic acid 3-*O*-$\beta$-D-(6′-*O*-galloyl)-glucopyranoside.[3]

Compound III (III), colorless prisms, mp 192—194°C, $[\alpha]_D$ −65.2° (acetone), $C_{20}H_{20}O_{14}\cdot 1/2H_2O$, gave a $^1$H-NMR spectrum almost identical with that of compound II except for a two-proton singlet ($\delta$ 7.08) in the aromatic region. Enzymatic hydrolysis of III with tannase yielded gallic acid and a crystalline hydrolysate (IIIa), mp 197—201°C, $[\alpha]_D$ −13.2° (MeOH),

$C_{13}H_{16}O_{10}\cdot 3/2H_2O$. The $^1$H-NMR spectrum of IIIa shows an anomeric proton signal ($\delta$ 4.70, d, $J$=7 Hz) and an aromatic two-proton singlet ($\delta$ 7.18). Two double doublets ($\delta$ 4.38, $J$=6, 12 Hz; $\delta$ 4.74, $J$=2, 12 Hz) in the spectrum of III, attributable to the glucose $C_6$-protons and clearly distinguished from other sugar signals, were shifted upfield upon degalloylation. Further treatment of IIIa with crude hesperidinase gave glucose and gallic acid. Based upon these observations, coupled with $^{13}$C-NMR spectral data (Table I) consistent with a gallic acid 4-*O*-glucoside having a galloyl group at the $C_{6'}$-position, the structure of III was established as gallic acid 4-*O*-$\beta$-D-(6'-*O*-galloyl)-glucopyranoside.

TABLE I. $^{13}$C-NMR Data for Compounds II, III and IV ($\delta$ values)[a]

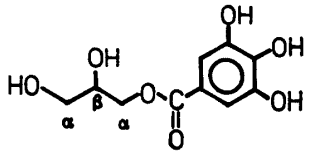
| | | II | III | IV |
|---|---|---|---|---|
| Glucose | $C_1$ | 103.5 | 107.1 | 95.4 |
| | $C_2$ | 74.2 | 74.3 | 73.2 |
| | $C_3$ | 76.6 | 76.9 | 77.0 |
| | $C_4$ | 71.0 | 70.7 | 70.6 |
| | $C_5$ | 75.5 | 76.1 | 75.5 |
| | $C_6$ | 65.1 | 63.9 | 64.3 |
| Aglycone | $C_1$ | 121.0 | 129.1 | |
| | $C_2$ | 113.3[b] | 110.1 | |
| | $C_3$ | 146.7 | 150.9 | |
| | $C_4$ | 139.8 | 137.8 | |
| | $C_5$ | 146.3 | 150.9 | |
| | $C_6$ | 110.7[b] | 110.1 | |
| | -COO- | 169.7 | 167.1 | |
| Galloyl | $C_1$ | 121.6 | 121.2 | 120.1, 120.9 |
| | $C_2$ | 109.9(2C) | 110.1(2C) | 110.0(2C), 110.3(2C) |
| | $C_3$ | 146.0(2C) | 146.0(2C) | 145.8(2C) |
| | $C_4$ | 140.9 | 139.1 | 139.1, 139.5 |
| | -COO- | 167.3 | 167.8 | 166.3, 167.5 |

a) Spectra measured in acetone-$d_6$+$D_2O$ at 25.05 MHz.
b) Assignments may be interchamged.

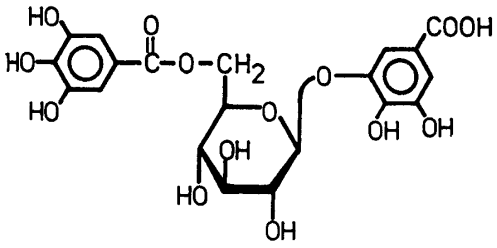
Compound IV (IV), colorless needles, mp 204—205°C, $[\alpha]_D$ −20.0° (acetone), $C_{20}H_{20}O_{14}\cdot 1/2H_2O$, contains two galloyl groups as revealed by the $^1$H- and $^{13}$C-NMR spectra. On acid hydrolysis IV furnished gallic acid and glucose. The $^1$H-NMR spectrum of IV shows the anomeric proton signal shifted considerably downfield ($\delta$ 5.76, d, $J$=7 Hz), indicating that a galloyl group is attached to this position through an ester linkage and that the mode of linkage is $\beta$. Another galloyl group was concluded to be present at the glucose $C_6$-position in view of the significantly deshielded signals analogous to those found in compounds II and III. These chemical and spectral data allowed the conclusive assignment of the structure IV for this compounds.[3]

Compound V (V), colorless needles, mp 137—138°C, $[\alpha]_D$ +21.3° ($H_2O$), $C_{13}H_{16}O_{10}\cdot 1/2H_2O$, gave a molecular ion peak at $m/z$ 332 in the FD-MS. The presence of a galloyl group and sugar moiety in V was easily deduced from the $^1$H-NMR spectrum which showed an aromatic singlet ($\delta$ 7.14) and complicated aliphatic signals ($\delta$ 3.2—5.2) integrated for seven protons. The $^{13}$C-NMR spectrum exhibits a duplicated signal pattern of sugar carbons. The chemical shifts of anomeric carbon signals at $\delta$ 97.4 and 93.1 corresponding to $\beta$ and $\alpha$, respectively, are in close agreement with those of glucose.

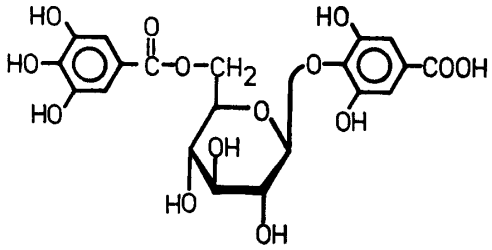
Methylation of V with dimethyl sulfate and potassium carbonate in dry acetone afforded as a main product a tetramethyl ether (Va), a white powder, mp 182—183°C, $[\alpha]_D$ −7.6° (acetone), $C_{17}H_{24}O_{10}$. The $^1$H-NMR spectrum of Va reveals deshielded methylene signals ($\delta$ 4.23, dd, $J$=6, 12 Hz; $\delta$ 4.62, $J$=2, 12 Hz) similar to those observed in compounds II, III and IV, indicating that the galloyl group is located at the $C_6$-position of the glucose moiety. It also shows an anomeric proton doublet ($\delta$ 4.12, $J$=7 Hz), together with one aliphatic and



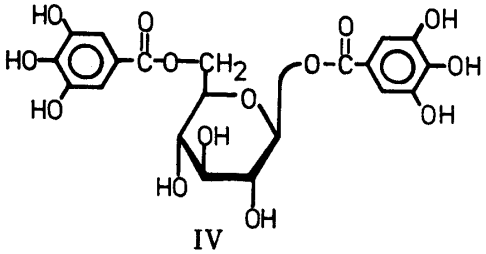
I



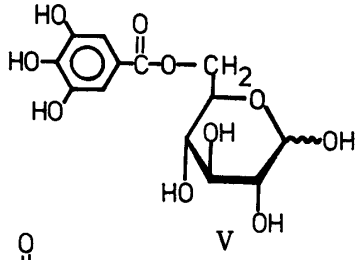
II



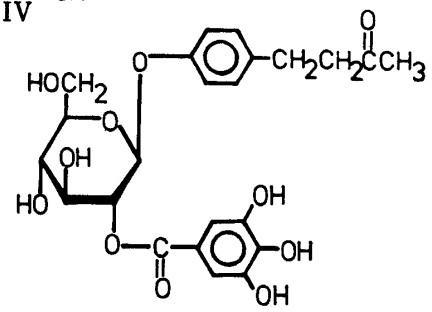
III



IV



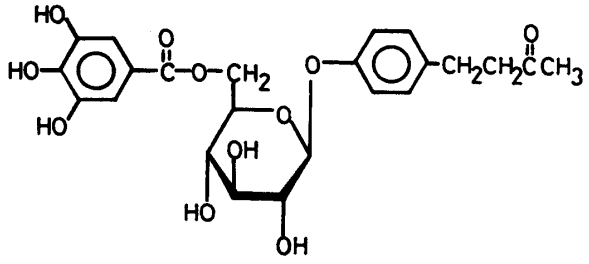
V



VI

three aromatic methoxyl signals [$\delta$ 3.36, 3.72, 3.81(X2)]. On the basis of these results the structure of compound V is assigned as 6-*O*-galloylglucose. Compound V does not show mutarotation, and it is considered from the spectral data that V exists in solution as an equilibrium mixture of $\alpha$- and $\beta$-forms.

Compound VI (VI), a white amorphous powder, $[\alpha]_D$ +7.5° (acetone), $C_{23}H_{26}O_{11}\cdot H_2O$, was obtained in a relatively high yield from the fraction containing lindleyin (VII). VI is structurally correlated with VII as revealed by the $^1$H-NMR spectrum, which shows signals due to a galloyl group ($\delta$ 7.16), $A_2B_2$-type aromatic protons ($\delta$ 6.87, d, $J$=8 Hz; $\delta$ 7.07, d, $J$=8 Hz), four methylene protons ($\delta$ 2.72, m) and an acetyl group ($\delta$ 2.07, s), along with sugar protons ($\delta$ 3.6—5.3). Enzymatic hydrolysis of VI with tannase yielded gallic acid and a crystalline hydrolysate (VIa), mp 103—105°C, $C_{16}H_{22}O_7\cdot 1/2H_2O$. The latter was identified as the glucoside of 4-(4′-hydroxyphenyl)-2-butanone[2,4] by direct comparison with a sample obtained by similar hydrolysis of lindleyin.



VII

The position of the galloyl group was determined as follows; methylation of VI with dimethyl sulfate and potassium carbonate in acetone gave the trimethyl ether (VIb), mp 154—155°C, $[\alpha]_D$ +0.6° (acetone), $C_{26}H_{32}O_{11}\cdot 1/2H_2O$. VIb was subsequently methylated by the Kuhn method to yield the permethyl ether which was, without further purification, treated with alkali and then methanolyzed. The methyl sugar, analyzed by gas–liquid chromatography (GLC), was found to be identical with methyl 3,4,6-tri-*O*-methylglucopyranoside. Accordingly, VI was concluded to be 4-(4′-hydroxyphenyl)-2-butanone 4′-*O*-β-D-(2″-*O*-galloyl)-glucopyranoside.

Although the presence of a large amount of gallic acid in rhubarb, along with the isolation of tannin-related compounds such as glucogallin (1-*O*-galloylglucose),[5] 1-*O*-galloyl-2-*O*-cinnamoylglucose[6] and 1,2,6-tri-*O*-galloylglucose,[2] suggested the occurrence of hydrolyzable tannins with higher molecular weights in rhubarb, no systematic study had yet been carried out in this field. Our successful isolation and characterization of various gallates represent an important step in overcoming the difficulties of elucidating the chemistry of tannins in rhubarb.

Further studies on the tannins in rhubarb are in progress, and in parallel with this, biological tests of the compounds isolated in this study are under way.

## Experimental

Melting points were determined on a Yanagimoto micro-melting point apparatus and are uncorrected. Optical rotations were taken with a JASCO DIP-4 digital polarimeter. FD-MS was obtained with a JEOL DX-300 spectrometer. $^1$H- and $^{13}$C-NMR spectra were taken with JEOL PS-100 and JEOL FX-100 spectrometers, respectively, using tetramethylsilane as an internal standard, and chemical shifts are given in δ (ppm). Column chromatography was carried out with Sephadex LH-20 (25—100 μ, Pharmacia Fine Chemical Co., Ltd.), Kieselgel 60 (70—230 mesh, Merck) and Avicel micro-crystalline cellulose (Funakoshi). Thin-layer chromatography (TLC) was conducted on precoated Kieselgel 60 $F_{254}$ plates (0.20 mm, Merck) and precoated Avicel SF cellulose plates (Funakoshi), and spots were located by ultraviolet illumination, and with $FeCl_3$, 10% $H_2SO_4$ and aniline–hydrogen phthalate spray reagents. Analytical GLC for methyl sugars was performed over 1% neopentyl glycol succinate polyester and 5% 1,4-butanediol succinate with nitrogen as the carrier gas.

**Isolation of Compounds I—VI**——Finely powdered rhubarb (雅黃, 3.0 kg) was extracted with 80% aqueous acetone at room temperature for six consecutive days. The acetone was removed by evaporation under reduced pressure (*ca.* 40°C), and the aqueous solution was partitioned three times with AcOEt. The aqueous layer, after removal of the solvent by evaporation, was subjected to Sephadex LH-20 column chromatography. Elution with $H_2O$ yielded uncharacterized materials negative to the $FeCl_3$ reagent. Subsequent elution with $H_2O$–EtOH (1: 1) afforded a fraction (60 g) containing relatively lower-molecular-weight phenolics including a large amount of anthraquinones. This fraction was rechromatographed over Sephadex LH-20 using EtOH to give three fractions (fractions I—III). Fraction I contained a mixture of anthraquinones, and was not examined further. Fraction II (27.6 g), consisting of monogallates, was separated by Sephadex LH-20 chromatography using acetone to yield compounds I (0.02 g), V (0.71 g) and VI (1.5 g). Fraction III was repeatedly chromatographed over Sephadex LH-20 using 60% aqueous MeOH and acetone with an increasing amount of $H_2O$ (0—12%) to give compounds II (0.18 g) and III (0.20 g). Compound IV obtained from this fraction was not pure, and was purified by further chromatography over Avicel cellulose with 2% AcOH as an eluent (yield: 0.14 g).

**Compound I (I)**——Colorless prisms ($H_2O$), mp 188—190°C, $[\alpha]_D^{26}$ +3.1° ($c$=0.45, MeOH), $[\alpha]_D^{22}$ +3.0° ($c$=0.53, acetone–$H_2O$). *Anal.* Calcd for $C_{10}H_{12}O_7$: C, 49.18; H, 4.95. Found: C, 49.31; H, 5.08. FD-MS $m/z$: 244 ($M^+$, 100%), 153 (1.3%). $^1$H-NMR (acetone-$d_6$+$D_2O$): 3.66 (2H, d, $J$=4 Hz, $-CH_2O-$), 3.96 (1H, m, $-\overset{|}{C}HO-$), 4.24 (2H, m, $-CH_2O-$), 7.13 (2H, s, galloyl H). $^{13}$C-NMR (acetone-$d_6$+$D_2O$): 63.7 (t, $-CH_2O-$), 66.5 (t, $-CH_2O-$), 70.7 (d, $-\overset{|}{C}HO-$), 109.9 (2C) (d, 2×galloyl $C_2$), 121.3 (s, galloyl $C_1$), 139.0 (s, galloyl $C_4$), 146.0 (2C) (s, 2×galloyl $C_3$), 167.5 (s, –COO–).

**Preparation of 1-*O*-Galloylglycerol**——A mixture of gallic acid (2.7 g), glycerol (10.0 g) and *p*-toluenesulfonic acid (0.2 g) was heated on an oil bath (120°C) for 3 h. The reaction mixture was applied to a Sephadex LH-20 column. Elution with EtOH yielded the monogalloylglycerol as colorless prisms ($H_2O$–MeOH) (1.6 g), mp 187—188°C. *Anal.* Calcd for $C_{10}H_{12}O_7$: C, 49.18; H, 4.95. Found: C, 49.04; H, 5.01. The $^1$H- and $^{13}$C-NMR spectra of this compound were identical with those of compound I.

**Compound II (II)**——A white amorphous powder, $[\alpha]_D^{22}$ −23.4° ($c$=0.7, acetone). *Anal.* Calcd for $C_{20}H_{20}O_{14}\cdot 1/2H_2O$: C, 48.68; H, 4.29. Found: C, 48.56; H, 4.35. $^1$H-NMR (acetone-$d_6$+$D_2O$): 4.25 (1H,

dd, $J$=6, 12 Hz, $C_{6'}$–H), 4.78 (1H, d, $J$=12 Hz, $C_{6'}$–H), 7.07 (2H, s, galloyl H), 7.34, 7.57 (each 1H, d, $J$=2 Hz, $C_{2,6}$–H). Hydrolysis of II with 1 N HCl for 4 h furnished gallic acid and glucose, which were identified by thin-layer co-chromatography with authentic samples.

**Hydrolysis of II with Tannase**——An aqueous solution (2 ml) of II (60 mg) was incubated with tannase at 37°C. After 10 min the solvent was evaporated off, and the residue was chromatographed over Sephadex LH-20 using EtOH to give gallic acid and a hydrolysate (IIa) as a white amorphous powder, $[\alpha]_D^{21}$ −54.2° ($c$=1.1, MeOH). *Anal.* Calcd for $C_{13}H_{16}O_{10}\cdot 3/2H_2O$: C, 43.46; H, 5.33. Found: C, 43.31; H, 4.98. $^1$H-NMR (acetone-$d_6$+$D_2O$): 4.94 (1H, d, $J$=7 Hz, anomeric H), 7.28, 7.41 (each 1H, d, $J$=2 Hz, galloyl H).

**Compound III (III)**——Colorless prisms ($H_2O$), mp 192—194°C, $[\alpha]_D^{22}$ −65.2° ($c$=0.81, acetone). *Anal.* Calcd for $C_{20}H_{20}O_{14}\cdot 1/2H_2O$: C, 48.68; H, 4.29. Found: C, 48.52; H, 4.28. $^1$H-NMR (acetone-$d_6$): 4.38 (1H, dd, $J$=6, 12 Hz, $C_{6'}$–H), 4.74 (1H, dd, $J$=2, 12 Hz, $C_{6'}$–H), 4.70 (1H, d, $J$=7 Hz, anomeric H), 7.08 (2H, s, $C_{2,6}$–H), 7.18 (2H, s, galloyl H).

**Hydrolysis of III with Tannase**——An aqueous solution (2 ml) of III (62 mg) was treated with tannase at 37°C. Work-up in the same way as described above gave gallic acid and a hydrolysate (IIIa), colorless prisms ($H_2O$), mp 197—201°C, $[\alpha]_D^{21}$ −13.2° ($c$=0.51, MeOH). *Anal.* Calcd for $C_{13}H_{16}O_{10}\cdot 3/2H_2O$: C, 43.46; H, 5.33. Found: C, 43.09; H, 5.08. $^1$H-NMR (acetone-$d_6$+$D_2O$): 4.70 (1H, d, $J$=7 Hz, anomeric H), 7.10 (2H, s, galloyl H). IIa was hydrolyzed with crude hesperidinase to give glucose and gallic acid, which were identified by comparison of the *Rf* values on TLC.

**Compound IV (IV)**——Colorless needles ($H_2O$), mp 204—205°C, $[\alpha]_D^{22}$ −20.0° ($c$=0.4, acetone). *Anal.* Calcd for $C_{20}H_{20}O_{14}\cdot 1/2H_2O$: C, 48.70; H, 4.29. Found: C, 48.38; H, 4.40. $^1$H-NMR (acetone-$d_6$): 4.36 (1H, dd, $J$=5, 12 Hz, $C_{6'}$–H), 4.60 (1H, dd, $J$=2, 12 Hz, $C_{6'}$–H), 5.76 (1H, d, $J$=7 Hz, anomeric H), 7.12, 7.16 (each 2H, s, galloyl H). Acid hydrolysis of IV in the same way as described before furnished gallic acid and glucose.

**Compound V (V)**——Colorless needles (MeOH–AcOEt), mp 137—138°C, $[\alpha]_D^{22}$ +21.3° ($c$=0.4, $H_2O$). *Anal.* Calcd for $C_{13}H_{16}O_{10}\cdot 1/2H_2O$: C, 45.75; H, 5.02. Found: C, 45.84; H, 5.30. FD-MS $m/z$: 332 ($M^+$, 100%). $^1$H-NMR (acetone-$d_6$): 3.2—5.2 (7H, m, sugar H), 7.14 (2H, s, galloyl H). $^{13}$C-NMR (acetone-$d_6$+$D_2O$): 64.5 (t, $\alpha$,$\beta$-$C_6$), 70.2 (d, $\alpha$-$C_4$), 70.9 (d, $\beta$-$C_4$), 71.1 (d, $\alpha$-$C_2$), 73.0 (d, $\alpha$-$C_5$), 74.1 (d, $\alpha$-$C_3$), 74.5 (d, $\beta$-$C_2$), 75.5 (d, $\beta$-$C_5$), 77.0 (d, $\beta$-$C_3$), 93.1 (d, $\alpha$-$C_1$), 97.4 (d, $\beta$-$C_1$), 109.7 (2C) (d, 2×galloyl $C_2$), 121.0 (s, galloyl $C_1$), 138.7 (s, galloyl $C_4$), 145.6 (2C) (s, 2×galloyl $C_3$), 167.1 (s, –COO–).

**Methylation of V**——A mixture of V (200 mg), dimethyl sulfate (2 ml) and anhydrous potassium carbonate (3.0 g) in dry acetone (15 ml) was refluxed for 3 h with stirring. After removal of inorganic salts, the filtrate was concentrated to a syrup, which was chromatographed over silica gel using AcOEt–MeOH–$H_2O$ (20: 2: 1) to yield the tetramethyl ether (Va) (50 mg), a white powder (MeOH), mp 182—183°C, $[\alpha]_D^{22}$ −7.6° ($c$=0.37, acetone). *Anal.* Calcd for $C_{17}H_{24}O_{10}$: C, 52.57; H, 6.23. Found: C, 52.47; H, 6.27. $^1$H-NMR (dimethylsulfoxide-$d_6$): 3.36 (3H, s, aliphatic OMe), 3.72 (3H, s, OMe), 3.81 (6H, s, OMe), 4.12 (1H, d, $J$=7 Hz, anomeric H), 4.23 (1H, dd, $J$=6, 12 Hz, $C_6$–H), 4.62 (1H, dd, $J$=2, 12 Hz, $C_6$–H), 7.22 (2H, s, galloyl H).

**Compound VI (VI)**——A white amorphous powder, $[\alpha]_D^{20}$ +7.5° ($c$=0.88, acetone). *Anal.* Calcd for $C_{23}H_{26}O_{11}\cdot H_2O$: C, 55.66; H, 5.69. Found: C, 56.04; H, 5.67. $^1$H-NMR (acetone-$d_6$): 2.07 (3H, s, $COCH_3$), 2.72 (4H, m, $-CH_2CH_2-$), 3.5—4.1 (5H, m, glu. $C_{3,4,5}$–H), 5.20 (2H, m, glu. $C_{1,2}$–H), 6.87 (2H, d, $J$=8 Hz, Ar H), 7.07 (2H, d, $J$=8 Hz, Ar H), 7.16 (2H, s, galloyl H). $^{13}$C-NMR (acetone-$d_6$+$D_2O$): 29.2 (q, $C_1$), 45.3 (t, $C_4$), 62.1 (t, glu. $C_6$), 71.2 (d, glu. $C_4$), 74.7 (d, glu. $C_2$), 75.5 (d, glu. $C_3$), 77.6 (d, glu. $C_5$), 100.3 (d, glu. $C_1$), 110.0 (2C) (s, 2×galloyl $C_2$), 117.5 (2C) (d, 2×$C_{2'}$), 121.3 (s, galloyl $C_1$), 130.0 (2C) (d, 2×$C_{3'}$), 136.3 (s, $C_{4'}$), 138.9 (s, galloyl $C_4$), 145.9 (2C) (s, 2×galloyl $C_3$), 156.6 (s, $C_{1'}$), 166.4 (s, –COO–), 209.3 (s, $C_2$).

**Hydrolysis of VI with Tannase**——An aqueous solution (5 ml) of VI (80 mg) was shaken with tannase at 37°C for 10 min, and the solution was concentrated to dryness under reduced pressure. The residue was treated with MeOH, and insoluble materials were filtered off. The filtrate, after concentration *in vacuo*, was applied to a Sephadex LH-20 column. Elution with MeOH gave gallic acid and a hydrolysate (VIa), mp 103—105°C. *Anal.* Calcd for $C_{16}H_{22}O_7\cdot 1/2H_2O$: C, 57.30; H, 6.91. Found: C, 57.39; H, 6.73. $^1$H-NMR (acetone-$d_6$+$D_2O$): 2.10 (3H, s, $COCH_3$), 2.78 (4H, m, $-CH_2CH_2-$), 3.4—4.1 (6H, m, sugar H), 4.92 (1H, d, $J$=7 Hz, anomeric H), 7.00 (2H, d, $J$=8 Hz, Ar H), 7.16 (2H, d, $J$=8 Hz, Ar H). The $^1$H-NMR spectrum coincided with that of the glucoside of 4-(4′-hydroxyphenyl)-2-butanone which was obtained by hydrolysis of lindleyin.[2]

**Permethylation of VI followed by Methanolysis**——A mixture of VI (200 mg), dimethylsulfate (1.5 ml) and potassium carbonate (2.0 g) in dry acetone (20 ml) was heated under reflux for 3 h. The reaction mixture was worked-up in the same way as for V to give a crude methylate, which was purified by silica gel column chromatography. Elution with AcOEt–MeOH (19: 1), followed by crystallization from AcOEt, yielded a trimethyl ether (VIb) (64 mg), colorless needles, mp 154—155°C, $[\alpha]_D^{22}$ +0.6° ($c$=0.36, acetone). *Anal.* Calcd for $C_{26}H_{32}O_{11}\cdot 1/2H_2O$: C, 59.97; H, 6.28. Found: C, 59.80; H, 6.24. $^1$H-NMR (acetone-$d_6$): 2.05 (3H, s, $COCH_3$), 2.73 (4H, m, $-CH_2CH_2-$), 3.77 (3H, s, $OCH_3$), 3.81 (6H, s, $OCH_3$), 5.1—5.3 (2H, m, glu. $C_{1,2}$–H), 6.88 (2H, d, $J$=8 Hz, Ar H), 7.08 (2H, d, $J$=8 Hz, Ar H), 7.32 (2H, s, galloyl H). A mixture of VIb (21 mg), methyl iodide (1 ml) and freshly prepared silver oxide (0.3 g) in dimethylformamide (1 ml) was stirred at room temperature for 4 h. The reaction mixture was diluted with $CHCl_3$, and insoluble

precipitates were filtered off. The filtrate, after removal of the solvent by evaporation under reduced pressure, gave a colorless residue which was refluxed in 1% methanolic NaOH (15 ml) for 30 min. The mixture was passed though a column of Dowex 50WX ($H^+$ form) equilibrated with $H_2O$, and the column was washed with MeOH. The eluate and washing were combined and concentrated *in vacuo* to give a colorless syrup, which was partially purified by chromatography over silica gel using AcOEt–MeOH (19: 1). Owing to the limited availability of the sample, this was used, without further separation, for methanolysis. The permethylate was heated in 1 N methanolic HCl for 4 h, and the mixture was passed though an Amberlite IRA-400 ($OH^-$ form) column. The eluate was concentrated to a syrup which, when analyzed by GLC, was shown to be identical with methyl 3,4,6-tri-*O*-methylglucopyranoside ($t_R$, 7.05 min; column, 5% 1,4-butandiol succinate; column temp., 190°C; flow rate, 40 ml/min, $t_R$, 2.2 min; 1% neopentyl glycol succinate polyester; column temp., 160°C; flow rate, 40 ml/min).

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## References and Notes

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