Phytochemistry, 1980, Vol. 19, pp. 1755–1759. Pergamon Press Ltd. Printed in England.

FRAGMENTATION PATTERN OF PERMETHYL 6-*C*-GLYCOSYLFLAVONES IN ELECTRON IMPACT MASS SPECTROMETRY

M. L. Bouillant,* A. Besset, J. Favre-Bonvin* and J. Chopin

Laboratoires de Chimie Biologique et de* Phytochimie, Université Claude Bernard, Lyon I, 69622 Villeurbanne, France

(*Received* 31 *October* 1979)

Key Word Index—6-*C*-glycosylflavones; MS fragmentation pattern; structural identification; synthesis.

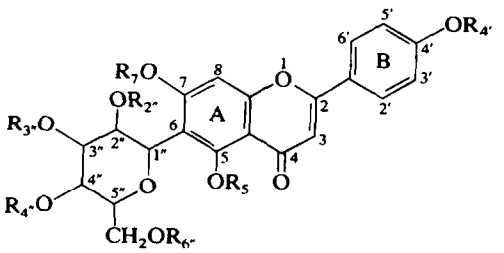
Abstract—A mass spectral fragmentation pattern of permethyl 6-*C*-glycosylflavones is proposed from the MS data of permethyl derivatives mono-*O*-deuteriomethylated in the 2″-, 3″-, 4″- or 6″-positions. The synthesis of these compounds via *O*″-glycosyl-6-*C*-glucosylflavones is described.

INTRODUCTION

In previous work [1] we have shown that all permethylated *C*-glycosylflavones give well-defined mass spectra including, in all cases, an important molecular peak. The observed fragmentations are characteristic of the nature and position of the sugar and 6-C- and 8-*C*-glycosylated derivatives are clearly differentiated. In unsymmetrical (6-*C*-gly≠8-*C*-gly) 6,8-di-*C*-glycosylflavones the nature of the sugar in both the 6- and 8-positions can be determined.

In a further study [2] we extended this method to the structural determination of *O*-glycosyl *C*-glycosylflavones, which frequently occur naturally in plants. Permethyl 6-*C*-glycosylflavones *O*-glycosylated on a phenolic hydroxyl group were easily distinguished from the isomeric 6-*C*-diglycosylflavones (*O*-glycosylated on a sugar hydroxyl) and in both types the position of the *O*-glycosidic bond can be deduced. This work required the synthesis of 6-*C*-diglycosylflavones (**1–4**) as reference compounds in which the *O*-glycosyl sugar was bound in turn to each hydroxyl group of the *C*-glucosyl unit. After permethylation, the removal of the *O*-glycosyl moiety by acid hydrolysis led to permethyl derivatives (**8–11**) with only one free hydroxyl group in the 2″-, 3″-, 4″- or 6″-positions. All these compounds can be differentiated by their MS [3]. Deuteriomethylation of this free hydroxyl group led to the corresponding mono-*O*-deuteriomethyl permethyl compounds (**12–15**), which, with some other derivatives: [permethyl-6-*C*-glucosylapigenin (**7**), 5,7,4′-tri-*O*-methyl-2″,3″,4″,6″-tetra-*O*-deuteriomethyl 6-*C*-glucosylapigenin (**16**), perdeuteriomethyl swertisin (7-*O*-methyl-6-*C*-glucosylapigenin) (**17**), perdeuteriomethyl 6-*C*-glucosylapigenin (**18**) and the permethyl derivative of the 3″-*O*-benzyl-6-*C*-glucosyl acacetin (**5**)], provided an explanation for the characteristic differences in MS fragmentation of each permethyl *O*-substituted 6-*C*-glucosylflavone. In the present work, we are able to confirm the rules established earlier, in a rather empirical fashion [1–3].

Table 1. *C*-glycosylflavones studied



	R_5	R_7	$R_{4'}$	$R_{2''}$	$R_{3''}$	$R_{4''}$	$R_{6''}$
1	H	H	Me	Rha	H	H	H
2	H	H	Me	H	Rha	H	H
3	H	H	Me	H	H	Glc	H
4	H	H	Me	H	H	H	Rha
5	H	H	Me	H	Bz	H	H
6	H	H	Me	H	H	H	Tr
7	Me	Me	Me	Me	Me	Me	Me
8	Me	Me	Me	H	Me	Me	Me
9	Me	Me	Me	Me	H	Me	Me
10	Me	Me	Me	Me	Me	H	Me
11	Me	Me	Me	Me	Me	Me	H
12	Me	Me	Me	CD_3	Me	Me	Me
13	Me	Me	Me	Me	CD_3	Me	Me
14	Me	Me	Me	Me	Me	CD_3	Me
15	Me	Me	Me	Me	Me	Me	CD_3
16	Me	Me	Me	CD_3	CD_3	CD_3	CD_3
17	CD_3	Me	CD_3	CD_3	CD_3	CD_3	CD_3
18	CD_3	CD_3	CD_3	CD_3	CD_3	CD_3	CD_3

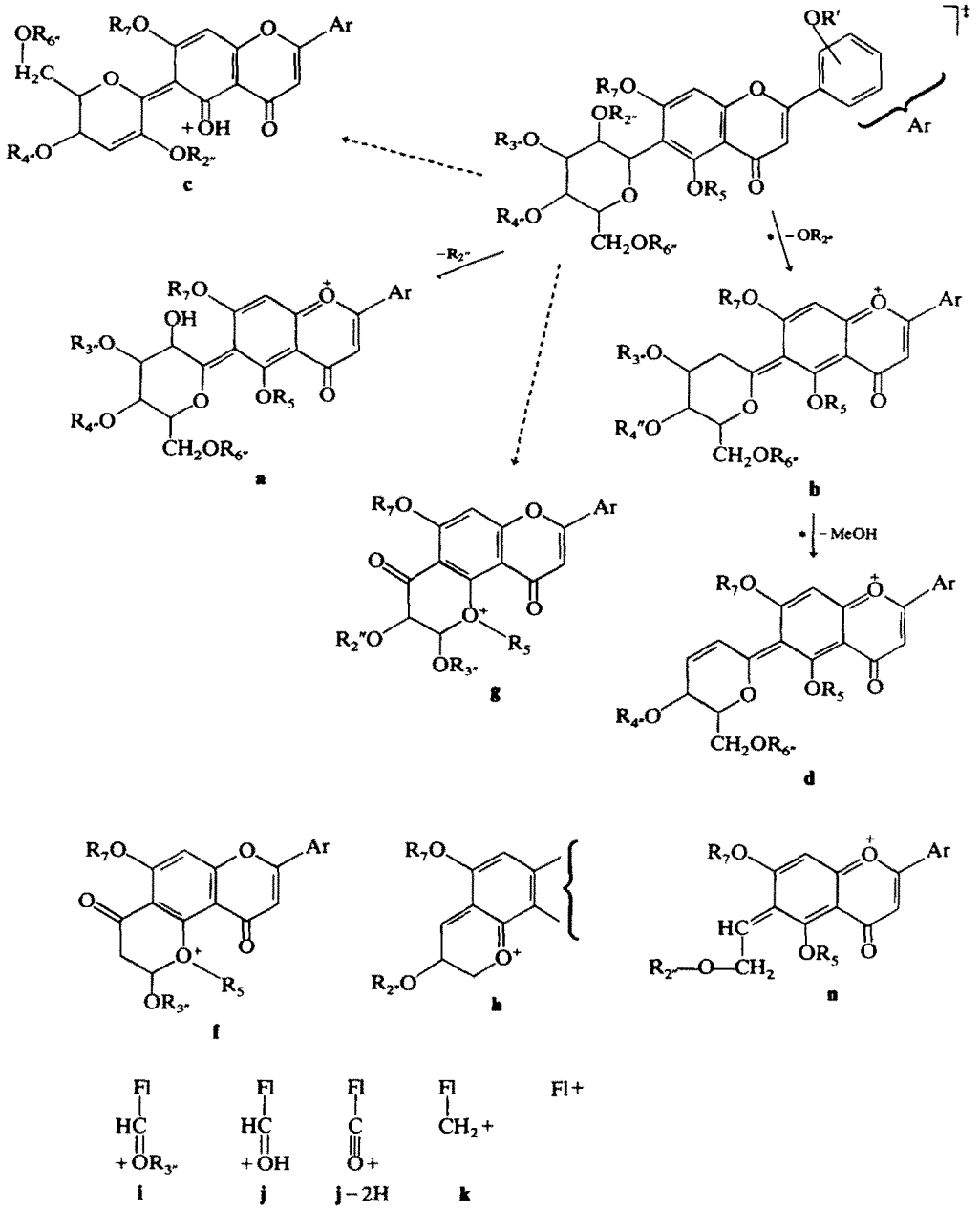
Rha = rhamnosyl, Glc = glucosyl, Me = methyl, Bz = benzyl, Tr = trityl.

RESULTS AND DISCUSSION

From the MS data noted in Table 2 we deduced the tentative fragmentation pattern shown in Scheme 1. MS fragmentation of permethyl 6-*C*-glycosylflavones occurs with gradual removal of the different carbon

Table 2. MS (%) data of permethyl and deuteriomethyl 6-*C*-glycosylflavones. Main peaks ≥5%

Peak		Compound 7	12	13	14	15	16	17	18	PM 5
	m/e	530	533	533	533	533	542	548	551	60
M^+	%	30	56	27	36	27	30	27	13	37
	M−15	20	3	22	22	22	—	—	—	25
a	M−18	—	22	—	—	—	20	13	14	—
	M−91	—	—	—	—	—	—	—	—	—
	M−31	78	30	67	69	77	—	—	—	100
b	M−34	—	73	17	—	—	71	48	40	—
	M−107	—	—	—	—	—	—	—	—	33
	M−47	12	18	—	12	12	—	—	—	—
	M−50	—	—	13	—	—	13	—	—	—
c	M−52	—	—	—	—	—	—	6	6	—
	M−123	—	—	—	—	—	—	—	—	37
	M−63	3	3	—	2	3	—	—	—	—
	M−66	—	3	3	3	—	—	—	—	—
d	M−69	—	—	—	—	—	2	2	2	—
	M−70	—	—	—	—	—	—	2	2	—
	M−139	—	—	—	—	—	—	—	—	9
	M−103	15	15	14	—	—	—	—	—	15
	M−106	—	—	—	15	13	—	—	—	—
g	M−109	—	—	—	—	—	15	9	9	—
	M−179	—	—	—	—	—	—	—	—	—
	M−133	7	—	8	—	—	—	—	—	7
	M−136	—	6	—	8	7	—	—	—	—
f	M−142	—	—	—	—	—	8	4	6	—
	M−209	—	—	—	—	—	—	—	—	—
	M−161	12	13	—	—	—	—	—	—	—
	M−164	—	—	16	14	14	—	—	—	—
n	M−170	—	—	—	—	—	9	9	10	—
	M−237	—	—	—	—	—	—	—	—	22
	M−163	15	16	—	—	—	—	—	—	—
	M−166	—	—	16	16	16	—	—	—	—
h	M−172	—	—	—	—	—	17	—	—	—
	M−173	—	—	—	—	—	—	8	9	—
	M−239	—	—	—	—	—	—	—	—	32
	M−175	100	14	100	16	—	—	—	—	91
	M−178	—	100	8	100	100	—	—	—	—
i	M−184	—	—	—	—	—	100	100	100	—
	M−251	—	—	—	—	—	—	—	—	26
	M−189	19	—	—	—	—	—	—	—	—
	M−192	—	17	19	21	19	—	—	—	—
j	M−201	—	—	—	—	—	14	12	18	—
	M−265	—	—	—	—	—	—	—	—	57
	M−191	12	—	—	—	—	—	—	—	—
	M−194	—	8	12	11	11	—	—	—	—
j-2	M−203	—	—	—	—	—	8	5	6	—
	M−267	—	—	—	—	—	—	—	—	50
	M−205	16	—	—	—	—	—	—	—	—
	M−208	—	13	16	13	15	—	—	—	—
k	M−217	—	—	—	—	—	12	5	9	—
	M−281	—	—	—	—	—	—	—	—	47
	M−207	12	—	—	—	—	—	—	—	—
	M−210	—	9	13	11	11	—	—	—	—
k−2	M−218	—	—	—	—	—	5	4	7	—
	M−219	—	—	—	—	—	12	4	9	—
	M−283	—	—	—	—	—	—	—	—	35
	M−219	13	—	—	—	—	—	—	—	—
	M−222	—	10	16	12	13	—	—	—	—
l	M−231	—	—	—	—	—	12	5	4	—
	M−295	—	—	—	—	—	—	—	—	36



Scheme 1. Fragmentation pattern of PM 6-*C*-glycosylflavones. R = Me, Fl = permethylflavone, * metastable transition.

atoms of the sugar leading to important ions (**a**, **b**, **c**, etc.) until the aglycone in remains (**1**). In the present study, we explain the part taken by each sugar substituent in this characteristic fragmentation.

2″-Substituent

As shown by the MS of **12**, the substituent in the 2″-position is involved in the losses giving rise, from the molecular ion, to the first (**a**) ($M-CD_3\cdot$) and the second (**b**) ($M-OCD_3\cdot$) main peaks in the spectrum. When an *O*-glycosyl substituent is in this position, the same peaks are obtained by loss of the PM glycosyl and PM glycosyloxy radicals [2], respectively. This substituent remains alone, in ions **h** and **n**.

3″-Substituent

The MS of compound **13** has shown that the substituent in 3″-position is mainly characterized by ion **i**, base peak, which is formed after cleavage of the C_1–C_2· and C_1–O bonds, by migration of the C_3· substituent to the anomeric C_1·, as observed in the MS of permethyl carbohydrates [4]. This result is confirmed by the MS of the permethyl derivative of 3″-*O*-benzyl-6-*C*-glucosylapigenin (**5**) in which the base peak is the ion Ar–CH=$\overset{+}{O}$–CH_2-Ph, homologous to **i**. The 3″-substituent is also involved, together with the phenolic substituent in the 5-position (cf. MS of **13**, **16** and **17**), in the loss giving rise to ion **c** and its removal from ion **b** leads to ion **d** (metastable transition). Ion **c**

(M−47 from **12**, **14** and **15**; M−50 from **13** and **16** and M−52 from **17** and **18**) comes from the loss of the methoxyl group in the 3″-position, a CH_2 group from the 5-OMe and two H atoms from an unknown origin.

4″- and 6″-substituents

As shown by the MS of **14** and **15**, no outstanding characteristics allow one to differentiate between the 4″- and 6″-methoxyl or deuteriomethoxyl groups. Both remain in the ions **a**, **b**, **c** and **d**, and both are lost in other ions. However the participation (16%) of the 4″-substituent to the ion **i** could explain the differences in the relative intensities of peaks **i** and **j** which distinguish the isomeric 4″- and 6″-monohydroxyl compounds **10** and **11** (see ref. [3]).

Aglycone substituents (ring A)

The MS of **16** and **17**, the phenolic substituent in the 5-position must be involved in the above-mentioned ions **c** and **d** and also in ion **h**, whereas the 7-methoxyl was unchanged (cf. MS of **17** and **18**). This difference in behaviour is consistent with their respective positions on the flavone nucleus and can be correlated with the great differences between the MS fragmentation of permethyl 6- and 8-*C*-glycosylflavones. The latter have been shown (1) to give simpler spectra in which, from the molecular ion, the sugar is almost completely lost to produce the base peak **i**: Ar—CH=$\overset{+}{O}$Me followed by the ion series **j**: Ar—CH=$\overset{+}{O}$H, **k**: Ar—CH_2+ until the aglycone ion **l**: Ar+.

Aglycone substituents (ring B)

In previous work [1], it was shown that ring B had no influence on the MS fragmentation but only on the relative intensities of the peaks. This is true if ring B substituents are methoxyl groups, but not when they are permethyl glycosyl groups (cf. [2], MS fragmentation pattern of the permethyl derivatives of 3′- and 4′-*O*-glucosyl 6-*C*-glucosyl-luteolin).

Synthesis of deuteriomethyl compounds

Access to mono-*O*-deuteriomethyl permethyl 6-*C*-glucosylflavones was made possible by the synthesis of some 6-*C*-diglycosylflavones. Permethylation and acid hydrolysis of the latter lead to mono-hydroxy permethyl derivatives, which can be deuteriomethylated. Thus mono-*O*-deuteriomethylpermethyl 6-*C*-glucosylapigenins **12**–**15** were obtained by respective treatment of the hexa-*O*-methyl 6-*C*-glucosylapigenins **8**–**11** with CD_3I in DMF–NaH mixture. 5,7,4′,3″,4″,6″-Hexa-*O*-methyl-6-*C*-glucosylapigenin (**8**) was obtained by acid hydrolysis of the permethyl derivative of 6-*C*-neohesperidosylacacetin (isomargariten) (**1**), the synthesis of which was previously described [5]. 5,7,4′,2″,4″,6″-Hexa-*O*-methyl-6-*C*-glucosylapigenin (**9**) was obtained by acid hydrolysis of the permethyl derivative of synthetic 6-*C*-rungiosylacacetin (**2**) or by hydrogenolysis of permethyl 3″-*O*-benzyl-6-*C*-glucosylacacetin (**5**). 5,7,4′,2″,3″,6″-Hexa-*O*-methyl-6-*C*-glucosylapigenin (**10**) is the acid-hydrolysis product of permethyl 6-*C*-cellobiosylacacetin (**3**) and 5,7,4′,2″,3″,4″-hexa-*O*-methyl-6-*C*-glucosylapigenin (**11**) the hydrolysis product of both permethyl 6-*C*-rutinosylacacetin (**4**) and permethyl 6″-*O*-trityl-6-*C*-glucosylacacetin (**6**).

All 6-*C*-diglycosylflavones were synthesized using the same method as for **1** [5] by condensing acacetin (5,7-dihydroxy-4′-methoxyflavone) in methanolic alkaline medium (LiOMe) with the suitable *O*-acetylglycosyl halide: α-bromo-hepta-*O*-acetylneohesperidose for **1**, α-bromo-hepta-*O*-acetylrungiose for **2**, α-bromo-octa-*O*-acetylcellobiose for **3** and α-bromo-hepta-*O*-acetylrutinose for **4**. The same condensation method was used to synthesize **5**, the sugar halide being α-bromo-3-*O*-benzyl-2,4,6-tri-*O*-acetyl-D-glucopyranose.

EXPERIMENTAL

MS were recorded on an AEI MS 902 spectrograph to 70 eV. Temps (sample and source in the same order) varied between 150 and 190°.

Chromatography—free compounds. PC or cellulose TLC in 5% HOAc (1); 15% HOAc (2); *n*-BuOH–HOAc–H_2O (BAW), 4:1:5 (3); *n*-BuOH– 27% HOAc, 1:1 (4); and Si gel TLC in EtOAc–Py–H_2O–MeOH (APEM), 80:12:10:5 (5). Permethyl (PM) and deuteriomethyl compounds: Si gel TLC in $CHCl_3$–EtOAc–Me_2CO, 5:4:1 (6) or 5:1:4 (7). *C*-Glycosyl apigenins or acacetins were violet-black in UV light and yellow with alkali; 6-*C*-glycosyl compounds gave red and 8-*C*-glycosyl compounds brown spots with diazotized benzidine. PM 6-*C*-glycosyl apigenins had a deep blue and PM 8-*C*-glycosyl isomers a light blue fluorescence.

Permethylation or deuteriomethylation. Less than 1 mg of substance in DMF (2 ml) was added, under dry N_2, to NaH (~100 mg), previously washed with hexane and then MeI or CD_3I (0.5 ml) was added. After 1 hr the mixture was cautiously diluted with H_2O and extracted with $CHCl_3$. After washing (5 or 6×) with H_2O, $CHCl_3$ was evapd and the derivative purified by TLC on Si gel in solvent (6) or (7). Deuteriomethylation of **8**, **9**, **10** and **11** led to **12**, **13**, **14** and **15**. To synthesize **16**, 6-*C*-glucosylacacetin was first methylated with CH_2N_2 in MeOH and, after purification, 5,7,4′-tri-*O*-methyl-6-*C*-glucosylapigenin was perdeuteriomethylated. **17** is the PM derivative of 7-*O*-methyl-6-*C*-glucosylapigenin (natural swertisin) and **18** is the perdeuteriomethyl (PDM) derivative of 6-*C*-glucosylapigenin (isovitexin). Chromatography in solvent (6): **12** 0.31, **13** 0.32, **14** 0.32, **15** 0.32, **17** 0.31, **18** 0.31, **7** 0.33.

Acid hydrolysis. A few mg of the PM derivative of the 6-*C*-diglycosylflavone was heated in sealed tube in MeOH–4N HCl 1:1 (2 ml) at 100–110° for 2 hr. After cooling, the soln was diluted and extracted with $CHCl_3$. After washing until neutral, the extract was concd and chromatographed on Si gel in solvent (7). Hydrolysis products gave deep blue fluorescent spots that have lower R_fs than the starting compounds: **8** 0.42, **9** 0.40, **1** 0.43, **11** 0.48; in solvent (**6**) **10** 0.12.

3″-O-α-L-Rhamnopyranosyl-6-C-β-D-glucopyranosylacacetin (**2**). Acetobromorungiose from HBr in HOAc treatment [6] of peracetylrungiose (1,2,4,6-tetra-*O*-acetyl-3-*O*-(2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl)-D-glucopyranose) (**7**) (1.4 g) in Et_2O (10 ml) was added to a soln of acacetin (67 mg) and LiOMe (Li 30 mg) in MeOH (10 ml) with shaking for 3 hr. The mixture was neutralized with 2 N-HCl and left overnight at room temp. The solvents were removed under vacuum and the residue extracted with H_2O (50 ml). Residual acacetin was removed by filtration and extraction with Et_2O (4×20 ml), while glycosylacacetins were extracted with *n*-BuOH (5×20 ml). The *n*-BuOH was evapd and the

glycoside mixture chromatographed on paper in solvent (1). 6-C-Rungiosylacacetin R_f 0.73, Si gel TLC 0.45 (5), red with diazotized benzidine was eluted and permethylated. Permethyl derivative: Si gel TLC 0.33 (6), 0.89 (7), UV deep blue. MS *m/e* (%): 704 (M^+, 46); 689 (7); 673 (33); 559 (12); 545 (23); 529 (16); 515 (25); 513 (28); 501 (21); 499 (74); 485 (23); 483 (42); 467 (60); 427 (9); 425 (28); 397 (11); 371 (11); 369 (42); 368 (28); 355 (69); 341 (100); 325 (63); 311 (39). From the permethylation mixture, traces of the PM derivative of the isomeric 8-C-rungiosylacacetin were obtained. Si gel TLC 0.63 (7), UV light blue. MS *m/e* (%): 704 (M^+, 22); 690 (6); 675 (4); 559 (6); 545 (34); 544 (29); 516 (26); 515 (75); 501 (16); 499 (12); 485 (8); 467 (11); 397 (11); 369 (13); 355 (19); 342 (22); 341 (100); 326 (15); 325 (14); 311 (27).

3″-O-Benzyl-6-C-β-D-glucopyranosylacacetin (**5**). 2,4,6-Tri-O-acetyl-3-O-benzyl-α-D-glucopyranosyl bromide (**8**) (6 g) in Et_2O (50 ml) was condensed with acacetin (380 mg) in MeOH–LiOMe (40 ml) (250 mg Li) in the usual way. Residual acacetin was extracted with Et_2O, and O-benzyl glucosides with EtOAc. 3″-O-Benzyl 6-C-glucosylacacetin, red with diazotized benzidine, was separated from the O-glucosides by TLC on polyamide powder in MeOH (R_f 0.63). Si gel TLC 0.82 (**5**).

Permethyl derivative. R_f 0.56 (6) (UV deep blue) MS reported in Table 2. In the permethylation mixture, traces of the permethyl derivative of the isomeric 3″-O-benzyl-8-C-glucosylacacetin were obtained R_f 0.20 (UV light blue). MS *m/e*(%): 606 (M^+,52); 592 (M − 14, 100); 577 (11); 564 (11); 551 (11); 550 (15); 549 (26); 521 (22); 520 (15); 507 (19); 506 (19); 491 (15); 477 (13); 450 (7); 449 (15); 432 (15); 431 (44); 421 (15); 403 (19); 395 (33); 393 (26); 369 (7); 367 (19); 365 (15); 355 (19); 351 (26); 341 (30); 340 (22); 339 (26); 327 (15); 325 (26); 323 (19); 311 (22). Hydrogenolysis of permethyl derivative: A stream of H_2 was passed through a mixture of a few mg of the PM derivative of **5** and Pd/C in Ac_2O for 24 hr. **9** was obtained. Its purification was achieved by TLC on Si gel in solvent (6).

4″-O-β-D-Glucopyranosyl-6-C-β-D-glucopyraosylacacetin (**3**). Acetobromo-cellobiose (α-bromo-2,3,6-tri-O-acetyl-4-O-(2,3,4,6-tetra-O-acetyl)β-D-glucopyranosyl)-D-glucopyranose (**9**) (18 g) and acacetin (0.8 g) were condensed in MeOH–MeOLi (80 ml) (300 mg Li) in the usual way. The mixture of glycoside was chromatographed on a Polyamide (MN SC 6) column (90 cm; 2 cm) eluted by MeOH–H_2O. Crystalline 6-C-cellobiosylacacetin (63 mg) 3.7%) was obtained from 20% MeOH, mp 245–247°; UV λ_{max}^{MeOH} nm: 270 (log ε 4.37), 305 sh, 326 (4.35); +NaOH, 277, 293 sh, 370; +NaOAc 278, 293 sh, 367; +NaOAc–H_3BO_3, 271, 318, 330 sh; +$AlCl_3$ 261 sh, 279, 296 sh, 302, 345, 380; +$AlCl_3$–HCl 260 sh, 279, 295 sh, 300, 338, 378. Chromatography: 0.34 (**1**), 0.45 (**2**), 0.45 (**3**), 0.62 (**4**), 0.30 (**5**). Permethyl derivative: 0.73 (**7**) (deep blue); MS *m/e* (%): 734 (M^+, 22); 719 (6); 703 (18); 499 (18); 467 (8); 427 (5); 425 (5); 371 (19); 369 (24); 367 (8); 355 (100); 341 (25); 325 (10); 311 (7).

6″-O-α-L-Rhamnopyranosyl-6-C-β-D-glucopyranosylacacetin (**4**). Acetobromorutinose (α-bromo-2,3,4-tri-O-acetyl-6-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl)-D-glucopyranose (**10**) (14 g) and acacetin (600 mg) were condensed in MeOH–MeOLi (70 ml) (Li 330 mg), and the glycoside mixture chromatographed as described for **3**. Crystalline 6-C-rutinosylacacetin (9 mg) (0.7%), mp 184–187°; UV λ_{max}^{MeOH} nm: 271 (log ε 4.19), 305 sh, 326 (4.20); +NaOH 278, 295 sh, 372; +NaOAc 277, 294 sh, 356; +NaOAc–H_3BO_3 270, 326; +$AlCl_3$ 260 sh, 278, 295 sh, 302, 345, 380; +$AlCl_3$–HCl 260 sh, 278, 295 sh, 300, 338, 377. Chromatography: 0.54 (**1**), 0.66 (**2**), 0.55 (**3**), 0.67 (**4**), 0.39 (**5**). Permethyl derivative 0.78 (**7**) (UV deep blue); MS *m/e* (%): 704 (M^+ 19); 689 (10); 673 (22); 559 (15); 545 (12); 529 (8); 515 (13); 513 (23); 501 (10); 499 (14); 485 (21); 467 (8); 427 (13); 425 (5); 371 (19); 369 (24); 367 (8); 355 (100); 341 (26); 325 (15); 311 (13); Traces of free 8-C-rutinosylacacetin were also observed when mother liquors of crystallization were chromatographed on Si gel TLC in solvent (5) R_f 0.50, brown with diazotized benzidine. Permethyl derivative: R_f 0.50 (7), UV light blue.

6″-O-Trityl-6-C-glucosylacacetin (**6**). 6-C-Glucosylacacetin (2 mg) and trityl chloride (18 mg) in Py (4 ml) were left at room temp. for 12 days. On dilution with H_2O, the product separated. After drying, the crude product is permethylated by the usual method; the trityl group was removed from the PM derivative using MeOH–2 N HCl (1:1) at room temp. for 12 hr, leading to **11**.

REFERENCES

1. Bouillant, M. L., Favre-Bonvin, J. and Chopin J. (1975) *Phytochemistry*, **14**, 2267.
2. Bouillant, M. L., Besset, A., Favre-Bonvin, J. and Chopin, J. (1978) *Phytochemistry* **17**, 527.
3. Bouillant, M. L., Besset, A., Favre-Bonvin, J. and Chopin, J. (1979) *Phytochemistry*, **18**, 690.
4. Kochetkov, N. K. and Chizhov, O. S. (1966) *Adv. Carbohydr. Chem.* **21**, 39.
5. Chopin, J., Besset, A. and Bouillant, M. L. (1977) *C.R. Acad. Sci., Ser. C* **284**, 1007.
6. Fischer, E., Bergmann, M. and Rabe, A. (1920) *Chem. Ber.* **53**, 2362.
7. Birkhofer, L. and Hammes, B. (1973) *Liebig's Ann.* 731.
8. Finan, P. A. and Warren, C. D. (1962) *J. Chem. Soc.* 3089.
9. Pacsu, E. (1930) *J. Am. Chem. Soc.* **52**, 2571.
10. Zemplen G. and Gerecs, A. (1937) *Chem. Ber.* **70**, 1098.