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SUGAR RING ISOMERIZATION IN *C*-ARABINOSYLFLAVONES

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Key Word Index—*C*-Arabinosylflavones; sugar ring isomerization; 6-*C*-α-L-arabinopyranosylacacetin; 6-*C*-α-L-arabinofuranosylacacetin; 6-*C*-β-L-arabinopyranosylacacetin; 6-*C*-β-L-arabinofuranosylacacetin; 8-*C*-α-L-arabinopyranosylgenkwanin; 8-*C*-α-L-arabinofuranosylgenkwanin; 6,8-di-*C*-α-L-arabinopyranosylacacetin; EIMS.

Abstract—6-*C*-α-L-Arabinopyranosyl- and furanosylacacetins have been synthesized. They are isomerized by short acid treatment to give a mixture of the four anomer/ring size combinations without any Wessely–Moser isomerization. In the same conditions molludistin (8-*C*-α-L-arabinopyranosylgenkwanin) led only to a mixture of molludistin and 8-*C*-α-L-arabinofuranosylgenkwanin. This is the first demonstration of ring sugar isomerization in *C*-glycosylflavones. In usual solvent systems, α-anomers are easily separated from β-anomers, whereas corresponding pyranosyl and furanosyl anomers are not. However, they are easily separated after permethylation and characteristic features are found in the mass spectra of PM 6-*C*-arabinofuranosyl isomers.

INTRODUCTION

The most distinctive feature of *C*-glycosylflavonoids is their resistance towards acid hydrolysis that accounts for the difficulties encountered in the identification of the glycosyl residue. It was early recognized that partial isomerization often occurs under these conditions since saponarin (**1**) has been shown by Barger [1] and Nakaoki [2] to give glucose and a mixture of vitexin (**2**) and saponaretin (**3**).

The characteristic difference between the chromatographic properties of vitexin and saponaretin allowed Seikel and Geissman [3] to demonstrate that acid treatment of each compound gives a mixture of both and led them to consider saponaretin as a hydrolysis product in which the cyclic ether side chain of vitexin proposed by Evans *et al.* [4] would be opened into a linear polyhydroxylated side chain. On the other hand, the acid isomerization of orientin (**4**) and homoorientin (**5**) was first interpreted by Koeppen [5] as a simple epimerization of the cyclic side chain and only later [6] as a Wessely–Moser rearrangement, a conclusion simultaneously and independently reached by Horowitz and Gentili [7] about vitexin and saponaretin. This rearrangement implies hydrolytic opening of the flavone heterocycle and cyclodehydration of the intermediary β-diketone (**6**) without any structural modification of the sugar residue.

However, when 6-*C*-xylosyl-, 6-*C*-arabinosyl-, 6-*C*-galactosyl- and 6-*C*-rhamnosylapigenins became available on *C*-glycosylation of apigenin, it could be shown that acid treatment of 6-*C*-xylosyl-, 6-*C*-arabinosyl- and 6-*C*-galactosylapigenins gives on 2D-PC several spots showing the UV spectra and chromatographic properties of *C*-glycosylapigenins whereas, in the same conditions, 6-*C*-rhamnosylapigenin only gives two spots corresponding to the pair of Wessely–Moser isomers [8]. This could be ascribed to a further acid isomerization of the sugar heterocycle in the former compounds, but the available amounts precluded any structural study. Our interest in that field was renewed by the discovery of three natural 6,8-di-*C*-glycosylapigenins containing arabinose and glucose. Schaftoside from *Silene schafta* [9] was shown to be 6-*C*-β-D-glucopyranosyl-8-*C*-α-L-arabinopyranosylapigenin [10] and to give on acid treatment several isomers, of which one could be identified with 6-*C*-α-L-arabinopyranosyl-8-*C*-β-D-glucopyranosylapigenin prepared by *C*-arabinosylation of vitexin [11] and with a natural compound isolated from *Flourensia cernua* [12]. This Wessely–Moser isomer of schaftoside was, therefore, named isoschaftoside, the name neoschaftoside being given to another isomer, chromatographically indistinguishable from a natural compound co-occurring with schaftoside in *Catananche cerulea* [13]. Permethylation of these compounds and comparison of the mass spectra of their PM derivatives [14] led to the conclusion that neoschaftoside was, like schaftoside, a 6-*C*-glucosyl-8-*C*-arabinosylapigenin, their difference being, therefore, at the sugar level. The natural occurrence of *O*-L-arabinofuranosides then prompted us to synthesize a 6-*C*-arabinofuranosylflavone in order to compare it with its pyranosyl isomer and to study their acid isomerization. Later on, acid isomerization of molludistin [15] a natural 8-*C*-α-L-arabinopyranosylgenkwanin, could be examined and we now show that 8- as well as 6-*C*-arabinosylflavones undergoes a facile acid isomerization of the sugar residue leading to a mixture of anomeric *C*-arabinopyranosyl- and *C*-arabinofuranosylflavones [16].

RESULTS AND DISCUSSION

In previous work on *C*-glycosylation of 5,7-dihydroxyflavones, the resulting mixture of *O*- and *C*-glycosides was usually heated with an acid to hydrolyse *O*-glycosides before chromatographic separation of the reaction products. This simplification was no longer

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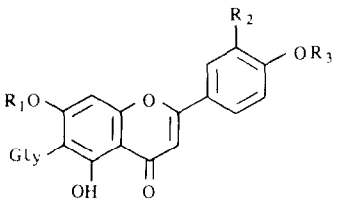


1 Gly = R_1 = Glc, R_2 = R_3 = H

3 Gly = Glc, R_1 = R_2 = R_3 = H

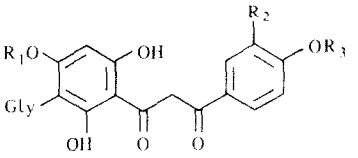
5 Gly = Glc, R_1 = R_3 = H, R_2 = OH

7 Gly = α – L – Araf, R_1 = R_2 = H, R_3 = Me

8 Gly = α – L – Arap, R_1 = R_2 = H, R_3 = Me

9 Gly = β – L – Arap, R_1 = R_2 = H, R_3 = Me

10 Gly = β – L – Araf, R_1 = R_2 = H, R_3 = Me



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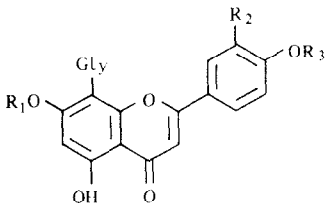
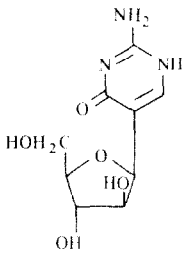


2 Gly = Glc, R_1 = R_2 = R_3 = H

4 Gly = Glc, R_1 = R_3 = H, R_2 = OH

12 Gly = α – L – Arap, R_1 = Me, R_2 = R_3 = H

13 Gly = α – L – Araf, R_1 = Me, R_2 = R_3 = H



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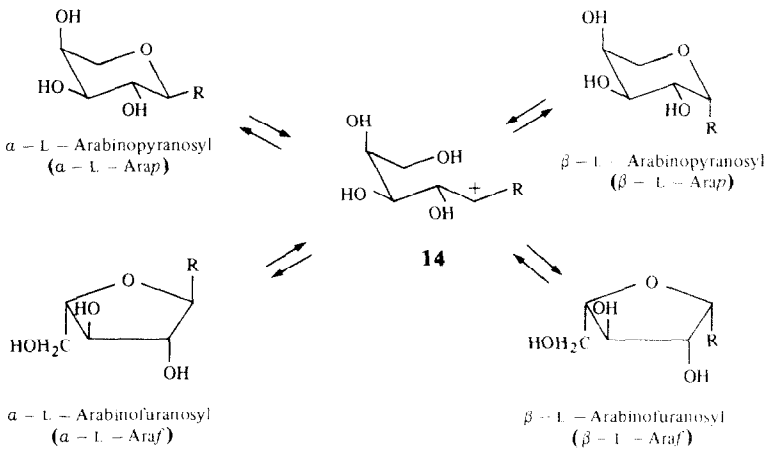

α – L – Arabinopyranosyl (α – L – Arap)

β – L – Arabinopyranosyl (β – L – Arap)

14

α – L – Arabinofuranosyl (α – L – Araf)

β – L – Arabinofuranosyl (β – L – Araf)

possible in the attempted *C*-arabinofuranosylation owing to the risk of acid isomerization of the sugar residue. This led us to choose acacetin (5,7-dihydroxy-4′-methoxyflavone) for *C*-arabinosylation in order to keep an apigenin-derived skeleton and to limit the number of possible *O*-glycosides in the reaction mixture.

No *C*-glycosylation being observed when using α-bromo-2,3,5-tri-*O*-benzoyl-L-arabinofuranose, we prepared α-bromo-2,3,5-tri-*O*-acetyl-L-arabinofuranose according to Bock and Pedersen [17]. Condensation of a very large excess of the latter with acacetin (molar ratio 50:1) in the presence of lithium methoxide in methanol and polyamide CC of the butanol-soluble fraction of the reaction mixture led to a few mg of a crystalline compound (7)

showing the UV spectra, chromatographic properties and colour reactions expected for a 6-C-glycosylacacetin. Its 6-C-arabinofuranosylacacetin structure was confirmed by the ^{1}H NMR spectrum of its perdeuteriomethyl (PDM) derivative in which all sugar protons could be identified by their coupling constants. However, the coupling constant (J = 7.6 Hz) and chemical shift (δ 5.47) of the anomeric proton did not indicate what the configuration was (later shown to be α). The EIMS of the permethyl (PM) derivative showed the same fragmentation pattern as PM 6-C-arabinopyranosylapigenin [14], but characteristic differences could be observed in the relative intensities of some ions and in the metastable peaks. The molecular ion is now the base peak and the importance of ions c [M − 47]$^+$, n[M − 117]$^+$ and h[M − 119]$^+$ [14] is considerably increased, whereas a new important ion [M − 79]$^+$ appears. On the other hand, the characteristic decrease of the ion m/z 88 in the mass spectra of PM arabinofuranosides compared with PM arabinopyranosides [18] is also found here to a lesser extent. Moreover, the metastable ions found in the mass spectrum of PM 6-C-arabinofuranosylacacetin correspond to the transitions [M]$^+$ → [M − 15]$^+$, [M − 15]$^+$ → [M − 47]$^+$ and [M − 47]$^+$ → [M − 79]$^+$ instead of the transitions [M]$^+$ → [M − 31]$^+$ and [M − 31]$^+$ → [M − 63]$^+$ deduced from the metastable ions present in the mass spectra of PM 6-C-glycopyranosylflavones [19]. In addition to 6-C-α-L-arabinofuranosylacacetin, another compound showing the UV spectra, chromatographic properties and colour reactions of acacetin-7-O-L-arabinofuranoside could be isolated, in too small amounts for a complete study.

In a parallel experiment, condensation of acacetin with a large excess (molar ratio 25:1) of α-bromo-2,3,4-tri-O-acetyl-L-arabinopyranose prepared according to ref. [20] led to 6-C-α-L-arabinopyranosylacacetin (**8**) and acacetin-7-O-L-arabinopyranoside. The structure of the former was assigned from the EIMS of its PM derivative which was identical with that of PM 6-C-arabinopyranosylapigenin and from the ^{1}H NMR spectrum of its PDM derivative in which the anomeric proton appears as a doublet (δ 4.78) with a coupling constant, J = 9.8 Hz. The presence of a di-C-arabinosylacacetin in the first fractions was confirmed after acid hydrolysis and the same 6,8-di-C-α-L-arabinopyranosylacacetin could be isolated when the condensation was followed by acid hydrolysis of the reaction mixture before separation by polyamide CC. It was characterized by the EIMS of its PM derivative which was found to be the same as those of the PM derivatives of di-C-pentosylapigenins isolated from *Melilotus alba* [21] and *Hymenophyton leptopodum* (HL-2) [22]. Moreover, the three PM derivatives showed the same migration on TLC, quite different from that of PM 6,8-di-C-β-D-xylopyranosylapigenin.

Chromatographic comparison of 6-C-α-L-arabinopyranosyl and furanosylacacetins showed they are not separated on cellulose or paper in BAW and 15% acetic acid or on silica gel in ethyl acetate–pyridine–water–methanol (80:12:10:5), i.e. in solvent systems classically used in the separation of C-glycosylflavones. An important consequence is that the existence of C-arabinofuranosylflavones may be overlooked if only cochromatography with standard C-arabinopyranosylflavones in usual solvent systems is used for comparison. However, two systems were found to give a good separation on Si gel TLC, namely ethyl acetate–methyl ethyl ketone–formic acid–water (5:3:1:1) and chloroform–methanol (5:1). Moreover, the PM derivatives are easily separated on Si gel TLC in chloroform–ethyl acetate–acetone (5:4:1).

Comparison of IR spectra (KBr) disclosed interesting differences in the region 1000–1100 cm^{-1} characteristic of the sugar residue: 6-C-arabinopyranosylacacetin as well as acacetin-7-O-arabinopyranoside present a strong absorption band around 1075 cm^{-1} whereas 6-C-arabinofuranosylacacetin as well as acacetin-7-O-arabinofuranoside present a minimum around 1075 cm^{-1} and a maximum around 1110 cm^{-1}.

Isopropylidenation of 6-C-α-L-arabinopyranosylacacetin with 2,2-dimethoxypropane according to Jarman and Ross [23] led to a monoisopropylidene ketal characterized by the mass spectrum of its PM derivative which showed interesting features: importance of the ions [M]$^+$ (498), [M − 15]$^+$ and [M − 31]$^+$ (100%) the persistence of which agrees with the presence of a 2″-methoxyl, presence of ions h–l [14] at m/z values encountered in PM 6-C-arabinopyranosylacacetin, but with a considerably reduced importance of i (from 100 to 16%) in agreement with a transfer of the 3″-methoxyl to the C-1″ of the PM sugar residue in the formation of this ion [19], presence of the transitions [M]$^+$ → [M − 31]$^+$ and [M − 31]$^+$ → [M − 89]$^+$ indicated by metastable ions, the latter corresponding to the loss of acetone characteristic of isopropylidene sugars [24].

After this preliminary characterization of the α-furanosyl and pyranosyl isomers, they were heated in methanol–4N HCl (1:1) at 100° in a sealed tube and the resulting mixture was studied by 2D-PC and TLC. It was observed that heating times of 45 min or less did not lead to any significant Wessely–Moser isomerization, since all compounds formed showed with diazotized benzidine the red colour of 6-C-glycosyl-5,7-dihydroxyflavones. They were best separated on Si gel in chloroform–methanol (5:1), the same four spots being obtained from both isomers. Two of these spots corresponded to the α-furanosyl and α-pyranosyl isomers, the latter being the main one, the two others to unknown compounds showing a higher migration.

The more easily available 6-C-α-L-arabinopyranosylacacetin was then repeatedly submitted to acid isomerization and the two unknowns could be isolated by prep. TLC in sufficient amounts for permethylation and perdeuteriomethylation. Mass spectrometry of the PM derivatives showed that both were 6-C-arabinosylacacetins, one being a 6-C-pyranosyl isomer, the other a 6-C-furanosyl isomer, from their similarity with those of the above PM 6-C-α-pyranosyl and 6-C-α-furanosyl isomers. The 6-C-β-L-arabinopyranosylacacetin (**9**) structure was deduced from the ^{1}H NMR spectrum of the corresponding PDM derivative which showed the anomeric proton as a broad singlet at δ 5.26, whereas in the ^{1}H NMR spectrum of the other PDM derivative, the anomeric proton appeared as a doublet at δ 5.80 with a coupling constant J = 7.2 Hz. In spite of the similar values of the coupling constants, the 6-C-β-L-arabinofuranosylacacetin (**10**) structure could be ascribed to this isomer (and α to the other) on the basis of the δ values of the anomeric protons, since it is well-known that the anomeric proton is found at lower field in aldofuranonucleosides bearing *cis*-related substituents on C-1′ and C-2′ [25]. This indeed is the case with the closely related C-nucleoside, 5-β-D-arabinofuranosylisocytosine (**11**),

which undergoes an acid isomerization leading to a mixture of the four α- and β-furanosyl and pyranosyl isomers in which the α-D-pyranosyl one is preponderant at equilibrium [26]. There is, thus, a striking similarity in the behaviour of 5-*C*-D-arabinosylisocytosine and 6-*C*-L-arabinosylacacetin towards acids since both give rise to the four possible anomers. Such a behaviour has been first observed with the nucleic acid *C*-nucleoside pseudouridine (5-*C*-β-D-ribofuranosyluracil) [27]. When natural molludistin (5,4′-dihydroxy-7-methoxy-8-*C*-α-L-arabinopyranosylflavone, **12**) isolated from *Mollugo distica* [15] was heated at 100° with methanol–4N HCl (1:1) for 45 min, no apparent isomerization could be detected by PC or TLC in the above solvent systems, even with chloroform–methanol (5:1). However TLC of the permethylated product disclosed two main bands, of which one showed the same R_f and mass spectrum as PM molludistin. The mass spectrum of the other was that of a PM 8-*C*-pentosylapigenin and the only significant differences with PM molludistin were an increase of the ratios $[M]^+ : [M-131]^+$ and *m/z* 101: 88, suggesting a furanosyl structure. This was confirmed by the ^{1}H NMR spectrum of the corresponding PDM derivative isolated from another experiment (heating time: 1.5 hr) which was quite similar to the spectrum of PDM 6-*C*-α-L-arabinofuranosylacacetin, the anomeric proton appearing at δ 5.68 as a doublet (J = 7.6 Hz) and the other arabinose protons being found at corresponding values with similar coupling constants. It follows that the only acid isomerization product isolated from molludistin is 8-*C*-α-L-arabinofuranosylgenkwanin (**13**), which in the free state is not separated from the starting product. In that case, the β-anomers are present in too low amounts, if any, to be isolated.

From these results, it can be concluded that 8-*C*-arabinosylflavones, as well as 6-*C*-arabinosylflavones, undergo an acid isomerization of the sugar heterocycle leading to a mixture of anomeric *C*-arabinopyranosyl- and *C*-arabinofuranosylflavones. This can be interpreted as the result of a protonation of the heterocyclic oxygen followed by a conversion of the oxonium ion into the benzylic carbonium ion (**14**) which can give the four possible anomers on returning to the oxonium form.

If acid isomerization of a mono-*C*-arabinosylflavone can give rise to four anomers, not less than 16 anomers can be produced from a 6,8-di-*C*-arabinosylflavone, four of which are symmetrical. An important consequence is that any observed acid isomerization of a di-*C*-glycosylflavone does not indicate an asymmetrical structure for the starting compound. For example, the symmetrical 6,8-di-*C*-α-L-arabinopyranosylapigenin (HL-2) from *Hymenophyton leptopodum* [22] was long thought to be an asymmetrical di-*C*-pentosylapigenin for this reason [28].

On the other hand, molludistin is an example of an unapparent acid isomerization, masked by the absence of separation of the isomers. In this respect, the chromatographic resemblance between anomers of the same configuration may be responsible either for an apparent absence of isomerization or of a reduction of the apparent number of isomers. For example, acid isomerization of schaftoside (6-*C*-glycosyl-8-*C*-arabinosylapigenin) should theoretically give four pairs of Wessely–Moser isomers, owing to the absence of isomerization of the glucose residue, and it seems likely that the four spots observed on 2D-PC of the reaction mixture contain not only schaftoside, neoschaftoside, isoschaftoside and neoisoschaftoside [29], but lesser amounts of other isomers. It seems appropriate at this point to stress the importance of permethylation for these studies in providing a good separation of the furanosyl and pyranosyl anomers and their easy characterization by EIMS if the arabinose residue is bound to C-6.

Another conclusion can be drawn from our results: isomerization of the arabinose ring is faster than Wessely–Moser isomerization, since the latter fortunately did not take place under our experimental conditions. Although no systematic study has yet been made of the relation between the rate of Wessely–Moser isomerization and flavone structure, it has been previously observed that isomerization of cytisoside (4′-*O*-methylvitexin) into isocytisoside requires much longer times of heating than isomerization of vitexin [30], in agreement with the resistance of our 6-*C*-arabinosylacacetins. That 7-*O*-methylation as well as 4′-*O*-methylation is effective in delaying Wessely–Moser isomerization is shown by the resistance of molludistin. Even in the case of *C*-arabinosylapigenins it seems that the sugar ring isomerization is faster, since it has been reported [29, 31] that neoschaftoside, rather than isoschaftoside, is the major isomer formed in short acid treatment of schaftoside and, similarly, that isoschaftoside is a better precursor of neoisoschaftoside than was neoschaftoside itself.

EXPERIMENTAL

Permethylation was carried out according to ref. [32].

C-Arabinofuranosylation of acacetin. To a stirred soln of Li (518 mg; 74 mmol) in MeOH (70 ml) were successively added acacetin (407 mg; 1.4 mmol) and a soln of α-bromo-2,3,5-tri-*O*-acetyl-L-arabinofuranose [17] (24.2 g; 70 mmol) in $CHCl_3$ (50 ml). After 30 min at room temp. the reaction mixture was neutralized with aq. 4 N HCl, concd and extracted with *n*-BuOH. This extract (*ca* 1 g) was chromatographed on a polyamide column (77 × 2 cm) eluted with H_2O (600 ml), 20% MeOH (1 l.), 40% MeOH (70 ml), 50% MeOH (800 ml), 60% MeOH (700 ml) and 80% MeOH (800 ml). Elution was followed by Si gel TLC in EtOAc–pyridine–H_2O–MeOH (80:12:10:5) (EPWM) and spraying with bisdiazotized benzidine. 6-*C*-α-L-Arabinofuranosylacacetin was eluted before acacetin-7-*O*-L-arabinofuranoside.

6-C-α-L-*Arabinofuranosylacacetin* (**7**). Mp 159–161° (50% MeOH). UV λ_{max}^{MeOH} nm (log ε): 270 (4.29), 326 (4.32): + NaOAc 278, 350; NaOAc + H_3BO_3 271, 323; $AlCl_3$ 278, 301, 344, 377i; + $AlCl_3$ + HCl 279, 300, 339, 376i; + NaOH 276, 368. PC (Whatman 1): R_f 0.52 (15% HOAc), 0.67 (BAW 4:1:5). TLC (cellulose): R_f 0.83 (BAW 27%); (Si gel) R_f 0.65 (EPWM), 0.77 (EtOAc–MeCOEt–HCOOH–H_2O, 5:3:1:1), 0.40 ($CHCl_3$–MeOH, 5:1). PM derivative: TLC (Si gel): R_f 0.39 ($CHCl_3$–EtOAc–Me_2CO 5:4:1); EIMS (70 eV) *m/z* (rel. int.): 486 $[M]^+$ (100), 471 $[M-15]^+$ (20), 455 $[M-31]^+$ (89), 439 $[M-47]^+$ (60), 407 $[M-79]^+$ (48), 369 $[M-117]^+$ (37), 367 $[M-119]^+$ (35), 355 $[M-131]^+$ (73), 341 $[M-145]^+$ (53), 325 $[M-161]^+$ (29), 309 $[M-175]^+$ (31); *m/z* 101:88 = 2.7; metastable ions: *m/z* 456.46 ($[M]^+ \rightarrow [M-15]^+$), 409.17 ($[M-15]^+ \rightarrow [M-47]^+$), 377.33 ($[M-47]^+ \rightarrow [M-79]^+$). PDM derivative: ^{1}H NMR (250 MHz, $CDCl_3$): δ_{TMS} 7.83 (2H, *d*, J = 9 Hz, H-2′, H-6′), 7.01 (2H, *d*, J = 9 Hz, H-3′, H-5′), 6.77 (1H, *s*, H-8), 6.60 (1H, *s*, H-3), 5.47 (1H, *d*, J = 7.6 Hz, H-1″), 4.54 (1H, *dd*, J = 7.6 and 5.7 Hz, H-2″), 4.28 (1H, *dd*, J = 7.2 and 4.9 Hz, H-4″), 3.85 (1H, *dd*, J = 5.7 and 7.2 Hz, H-3″), 3.60 (2H, *d*, J = 4.9 Hz, H-5″, H-5‴).

Acacetin 7-O-L-*arabinofuranoside.* UV λ_{max}^{MeOH} nm: 267, 321;

+ NaOAc 267, 322; + $AlCl_3$ 276, 300, 342, 381; $AlCl_3$ + HCl 273, 297, 334, 378; + NaOH decomposition. TLC (cellulose): R_f 0.86 (BAW 27%), 0.08 (15% HOAc); (Si gel) R_f 0.72 (EPWM), 0.60 ($CHCl_3$–MeOH, 5:1).

C-Arabinopyranosylation of acacetin. To a stirred soln of Li (420 mg 60 mmol) in MeOH (80 ml) were successively added acacetin (857 mg; 3 mmol) and a soln of β-bromo-2,3,4-tri-*O*-acetyl-L-arabinopyranose [20] (19.5 g; 57 mmol) in Et_2O (60 ml). After 30 min at room temp. the reaction mixture was neutralized with aq. 4 N HCl, concd and extracted with *n*-BuOH. This extract was chromatographed on a polyamide column (75 × 2 cm) eluted with H_2O (450 ml), 20% MeOH (300 ml), 50% MeOH (450 ml), 80% MeOH (600 ml) and MeOH. Elution was followed by Si gel TLC in EPWM and spraying with bisdiazotized benzidine and gave in the order 6,8-di-*C*-arabinosylacacetin, 6-*C*-α-L-arabinopyranosylacacetin and acacetin 7-*O*-L-arabinopyranoside.

6,8-Di-C-α-L-arabinopyranosylacacetin. UV λ_{max}^{MeOH} nm: 271, 324; + NaOAc 278, 334; + NaOAc + H_3BO_3 270, 315; + $AlCl_3$ 279, 304, 344, 380i; + $AlCl_3$ + HCl 279, 301, 340, 378i; + NaOH 276, 364. PM derivative: TLC (Si gel): R_f 0.12 ($CHCl_3$–EtOAc–Me_2CO, 5:4:1); EIMS (70 eV) *m/z* (rel. int) 660 $[M]^+$ (14), 645 $[M-15]^+$ (23), 629 $[M-31]^+$ (100), 613 $[M-47]^+$ (11), 599 $[M-61]^+$ (16), 571 $[M-89]^+$ (6), 541 $[M-119]^+$ (27), 529 $[M-131]^+$ (50), 515 $[M-145]^+$ (20), 499 $[M-161]^+$ (6), 497 $[M-163]^+$ (11).

6-C-α-L-Arabinopyranosylacacetin (**8**). Mp 153–155° (50% MeOH) UV λ_{max}^{MeOH} nm (log ε): 270 (4.27), 325 (4.29); + NaOAc 278, 350; + $AlCl_3$ 279, 300, 344, 380; + NaOH 276, 368. PC (Whatman 1): R_f 0.55 (15% HOAc), 0.69 (BAW 4:1:5). TLC (cellulose): R_f 0.81 (BAW 27%); (Si gel) R_f 0.64 (EPWM), 0.66 (EtOAc–MeCOEt–HCOOH–H_2O, 5:3:1:1), 0.35 ($CHCl_3$–MeOH, 5:1). PM derivative: TLC (Si gel): R_f 0.18 ($CHCl_3$–EtOAc–Me_2CO, 5:4:1); EIMS (70 eV) *m/z* (rel. int.): 486 $[M]^+$ (17), 471 $[M-15]^+$ (21), 455 $[M-31]^+$ (83), 439 $[M-47]^+$ (16), 369 $[M-117]^+$ (10), 367 $[M-119]^+$ (17), 355 $[M-131]^+$ (100), 341 $[M-145]^+$ (52), 325 $[M-161]^+$ (18), 311 $[M-175]^+$ (22); *m/z* 101: 88 = 0.5; metastable ions: 425.96 ($[M]^+ \rightarrow [M-31]^+$), 393.25 ($[M-31]^+ \rightarrow [M-63]^+$). PDM derivative: ^1H NMR (250 MHz, $CDCl_3$): δ_{TMS} 7.86 (2H, *d*, *J* = 9 Hz, H-2′, H-6′), 7.04 (2H, *d*, *J* = 9 Hz, H-3′, H-5′), 6.80 (1H, *s*, H-8), 6.62 (1H, *s*, H-3), 4.78 (1H, *d*, *J* = 9.8 Hz, H-1″), 4.34 (1H, *m*, H-2″), 4.30 (1H, *d*, *J* = 13 Hz, H-5″ eq), 3.92 (3H, *s*, OMe), 3.75 (1H, *br s*, $W_{1/2}$ = 8 Hz, H-4″), 3.47 (1H, *d*, *J* = 13 Hz, H-5″ax), 3.39 (1H, *m*, H-3″).

Acacetin 7-O-L-arabinopyranoside. Mp 133–137° (80% dioxane). UV λ_{max}^{MeOH} nm (log ε): 267 (4.26), 322 (4.29); + NaOAc 267, 322; + $AlCl_3$ 276, 299, 341, 380; + NaOH 282, 347. TLC (cellulose): R_f 0.77 (BAW 27%), 0.07 (15% HOAc); (Si gel) R_f 0.64 (EPWM), 0.48 ($CHCl_3$–MeOH, 5:1).

Acid isomerization of 6-C-α-L-arabinopyranosylacacetin. The compound (1–6 mg), in 2–5 ml MeOH–4N HCl (1:1) was heated in a sealed tube at 100° for 45 min. After neutralization with aq. 2 N NaOH, concn and extraction with *n*-BuOH, 2D-PC of the extract in BAW (4:1:5)–15% HOAc gave two spots: R_f 0.75/0.47 (α-anomers) and 0.82/0.24 (β-anomers). Separation of the extract into four spots was only obtained on Si gel TLC in $CHCl_3$–MeOH (5:1): R_f 0.35 (α-pyranosyl), 0.40 (α-furanosyl), 0.51 (β-pyranosyl), 0.55 (β-furanosyl).

6-C-β-L-Arabinopyranosylacacetin (**9**). TLC (Si gel) R_f 0.74 (EPWM), 0.85 (EtOAc–MeCOEt–HCOOH–H_2O, 5:3:1:1), 0.51 ($CHCl_3$–MeOH, 5:1). PM derivative: TLC (Si gel): R_f 0.12 ($CHCl_3$–EtOAc–Me_2CO, 5:4:1); EIMS (70 eV) *m/z* (rel. int.): 486 $[M]^+$ (25), 471 $[M-15]^+$ (14), 455 $[M-31]^+$ (61), 439 $[M-47]^+$ (13), 367 $[M-119]^+$ (13), 355 $[M-131]^+$ (100), 341 $[M-145]^+$ (51), 325 $[M-161]^+$ (16), 311 $[M-175]^+$ (16); *m/z* 101: 88 = 0.6; metastable ions: *m/z* 425.96 ($[M]^+ \rightarrow [M-31]^+$), 393.25 ($[M-31]^+ \rightarrow [M-63]^+$). PDM derivative: ^1H NMR (250 MHz, $CDCl_3$): δ_{TMS} 7.84 (2H, *d*, *J* = 9 Hz, H-2′, H-6′), 7.02 (2H, *d*, *J* = 9 Hz, H-3′, H-5′), 6.81 (1H, *s*, H-8), 6.60 (1H, *s*, H-3), 5.26 (1H, *br s*, H-1″), 4.04 (1H, *dd*, *J* = 3.5 and 8.5 Hz, H-Ara), 3.89 (3H, *s*, OMe), 3.82 (1H, *m*, $W_{1/2}$ = 9 Hz, H-Ara), 3.78–3.69 (2H, *m*, 2H-Ara), 3.64 (1H, *m*, $W_{1/2}$ = 10 Hz, H-Ara).

6-C-β-L-Arabinofuranosylacacetin (**10**). TLC (Si gel): R_f 0.74 (EPWM), 0.85 (EtOAc–MeCOEt–HCOOH–H_2O, 5:3:1:1), 0.55 ($CHCl_3$–MeOH, 5:1). PM derivative: TLC (Si gel): R_f 0.25 ($CHCl_3$–EtOAc–Me_2CO, 5:4:1); EIMS (70 eV) *m/z* (rel. int.): 486 $[M]^+$ (54), 471 $[M-15]^+$ (18), 455 $[M-31]^+$ (69), 439 $[M-47]^+$ (61), 407 $[M-79]^+$ (38), 369 $[M-117]^+$ (43), 367 $[M-119]^+$ (43), 355 $[M-131]^+$ (100), 341 $[M-145]^+$ (83), 325 $[M-161]^+$ (35), 309 $[M-175]^+$ (38); *m/z* 101: 88 = 4.9; metastable ions: *m/z* 456.46 ($[M]^+ \rightarrow [M-15]^+$), 409. 17 ($[M-15]^+ \rightarrow [M-47]^+$), 377.33 ($[M-47]^+ \rightarrow [M-79]^+$). PM derivative: ^1H NMR (250 MHz, $CDCl_3$): δ_{TMS} 7.84 (2H, *d*, *J* = 9 Hz, H-2′, H-6′), 7.01 (2H, *d*, *J* = 9 Hz, H-3′, H-5′), 6.77 (1H, *s*, H-8), 6.62 (1H, *s*, H-3), 5.80 (1H, *d*, *J* = 7.2 Hz, H-1″), 4.07 (1H, *dd*, *J* = 7.2 and 4.5 Hz, H-Ara), 3.89 (3H, *s*, OMe), 3.86 (1H, *m*, H-Ara), 3.75 (1H, *m*, H-Ara), 3.70 (2H, *d*, *J* = 5 Hz, H-5″, H-5‴).

Acid isomerization of molludistin (8-C-α-L-*arabinopyranosylgenkwanin*). The compound (2–6 mg) in 2–4 ml MeOH–4 N HCl (1:1) was heated in a sealed tube at 100° for 45 or 90 min. After repeated evaporations, the residue gave only one spot on TLC. After permethylation, TLC (Si gel) in $CHCl_3$–EtOAc–Me_2CO (5:4:1) gave two spots R_f 0.13 (PM molludistin), 0.17 (PM α-furanosyl).

8-C-α-L-Arabinofuranosylgenkwanin (**13**). PM derivative: EIMS (70 eV) *m/z* (rel. int.): 486 $[M]^+$ (100), 355 $[M-131]^+$ (42), 341 $[M-145]^+$ (37), 325 $[M-161]^+$ (10); *m/z* 101 > 88. PDM derivative: ^1H NMR (250 MHz, $CDCl_3$): δ_{TMS} 7.84 (2H, *d*, *J* = 9 Hz, H-2′, H-6′), 6.98 (2H, *d*, *J* = 9 Hz, H-3′, H-5′), 6.59 (1H, *s*, H-3), 6.40 (1H, *s*, H-6), 5.68 (1H, *d*, *J* = 7.6 Hz, H-1″), 4.56 (1H, *dd*, *J* = 7.6 and 5.7 Hz, H-2″), 4.31 (1H, *dd*, *J* = 6.4 and 4.5 Hz, H-4″), 4.00 (3H, *s*, OMe), 3.95 (1H, *dd*, *J* = 5.7 and 6.4 Hz, H-3″), 3.62 (2H, *d*, *J* = 4.5 Hz, H-5″, H-5‴).

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