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A FACILE PREPARATION OF ALKYL α-GLYCOSIDES OF THE METHYL ESTER OF *N*-ACETYL-D-NEURAMINIC ACID

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ABSTRACT

The reaction of methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-2-chloro-2,3,5-trideoxy-β-D-*glycero*-D-*galacto*-2-nonulopyranosonate with primary and secondary alcohols in the presence of silver salicylate affords, after *O*-deacetylation, stereospecifically the corresponding methyl (alkyl 5-acetamido-3,5-dideoxy-α-D-*glycero*-D-*galacto*-2-nonulopyranosid)onates. The preparation of methyl (neopentyl 5-acetamido-3,5-dideoxy-α-D-*glycero*-D-*galacto*-2-nonulopyranosid)onate in benzene solution shows that this glycosylation can be carried out in an inert solvent.

INTRODUCTION

Sialic acids play an important role in a large number of biological processes, as constituents of glycoproteins and glycolipids[1–4]. Frequently, they occupy terminal, non-reducing positions in the oligosaccharide chains of these biomolecules and are α-linked. In the framework of our structural studies of glycoconjugates, we have been concerned with the development of syntheses of sialic acid derivatives. Since α-linked *N*-acetyl-D-neuraminic acid (Neu5Ac) in a non-reducing position is the most common of sialic acids occurring in Nature, attention was focused on the preparation of alkyl α-glycosides of Neu5Ac. These glycosides have the aglycon group in an equatorial position.

The preparation of alkyl α-glycosides of Neu5Ac is usually performed with 5-acetamido-4,7,8,9-tetra-*O*-acetyl-2-chloro-2,3,5-trideoxy-β-D-*glycero*-D-*galacto*-2-nonulopyranosonic acid (**1**) or its methyl ester (**2**) and the appropriate alcohol under Koenigs–Knorr-like conditions in the presence of silver carbonate or mercury(II)-salts[5–8]. However, even with high concentrations of aglycon, by using the alcohol as solvent, yields are often moderate (30–60%) and long reaction times are required. Based on the finding that glycosyl halides react smoothly with alcohols in the presence of insoluble silver salts of dicarboxylic acids or hydroxy carboxylic acids[9–11], Eschenfelder and Brossmer[12,13] obtained slightly improved yields (50–70%) of per-

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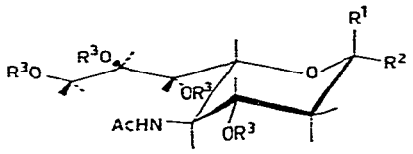

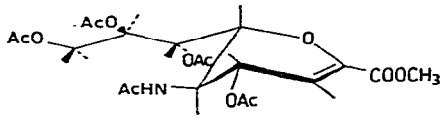

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1 R^1=Cl ; R^2=CO_2H ; R^3=Ac
2 R^1=Cl ; R^2=CO_2Me ; R^3=Ac
3 R^1=CO_2Me ; R^2=OMe ; R^3=Ac
4 R^1=CO_2Me ; R^2=OEt ; R^3=Ac
5 R^1=CO_2Me ; R^2=$OCHMe_2$; R^3=Ac
6 R^1=CO_2Me ; R^2=OCH_2CMe_3, R^3=Ac
7 R^1=CO_2Me ; R^2=$OCMe_3$, R^3=Ac
8 R^1, R^2=CO_2Me , Sal. ; R^3=Ac
Sal.= salicyloyl

10 R^1=OCH_2CMe_3 ; R^2=CO_2Me , R^3=Ac
11 R^1=CO_2Me ; R^2=OMe ; R^3=H
12 R^1=CO_2Me ; R^2=CEt ; R^3=H
13 R^1=CO_2Me ; R^2=$OCHMe_2$; R^3=H
14 R^1=CO_2Me ; R^2=OCH_2CMe_3 ; R^3=H
15 R^1, R^2=OAc, CO_2Me , R^3=Ac

O-acetylated Neu5Ac α-glycosides using a similar silver salt bound to a polymer. The activity of such salts is ascribed to the participation of a properly oriented carboxyl or hydroxyl group with the carboxyl anion[9,10,14].

Veinberg *et al.*[15] reported the enhancement of the Koenigs–Knorr reaction between 2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl bromide and methanol by a factor of 10^3–10^4 in the presence of silver salicylate. Our application of this method to the preparation of a number of alkyl β-D-gluco- and -galacto-pyranosides led to excellent yields, high stereoselectivity, and short reaction times, even for the more sterically hindered alcohols[16]. For glycosyl halides carrying a non-participating benzyl group vicinal to the anomeric centre, Wulff and Wichelhaus[17] showed that glycosylations with complex alcohols and silver salicylate also proceed with stereoselective inversion of anomeric configuration and that only minor amounts of glycosylated salicylic acid derivatives are formed.

Thus, the effectiveness of silver salicylate for the rapid and stereoselective formation of Neu5Ac α-glycosides from **2** was anticipated, and its demonstration by the preparation of a series of Neu5Ac α-glycosides is now reported.

RESULTS AND DISCUSSION

Treatment of **2** with methanol, ethanol, or 2-propanol in the presence of 1.5 equivalents of silver salicylate gave, exclusively, the corresponding methyl (alkyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-α-D-*glycero*-D-*galacto*-2-nonulopyranosid)onates (**3**–**5**). The reaction was complete within a few minutes, and was accompanied by a colour change of the insoluble silver salt almost immediately after its addition. The ^{1}H- and ^{13}C-n.m.r. spectra (Tables I and II) of the crude reaction products showed the absence of methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-2-*O*-salicyloyl-D-*glycero*-D-*galacto*-2-nonulopyranosonate (**8**) as well as of the alkene **9**. The ^{1}H-n.m.r. spectra showed only one double-doublet characteristic for H-3*eq* of Neu5Ac derivatives[18] in the region δ 2–3, indicating the presence of only

TABLE I

^{1}H-N.M.R. DATA[a,b] FOR METHYL (ALKYL 5-ACETAMIDO-3,5-DIDEOXY-α-D-*glycero*-D-*galacto*-2-NONULOPYRANOSID)ONATES AND THEIR PER-*O*-ACETYLATED DERIVATIVES

Compound	*Chemical shifts, δ (and multiplicities)*												*Aglycon*
	H-3eq (dd)	*H-3ax (dd)*	*H-4 (m)*	*H-5 (dd)*[d]	*H-6 (dd)*	*H-7 (dd)*	*H-8 (m)*	*H-9 (dd)*	*H-9′ (dd)*	*Me-ester (s)*	*NH (d)*	*OAc, NAc (s)*	
3[c,e]	2.570	1.947	4.856	4.064	4.127	5.332	5.430	4.317	4.108	3.816	5.141	2.163, 2.146, 2.048, 2.035, 1.888	3.323 (s) CH_3
4[c,f]	2.59	1.93	4.86	//	//	//	5.38	4.36	//	3.82	//	2.15, 2.15, 2.03, 2.03, 1.87	1.17 (t) CH_3 3.29 (m) CH′ // CH
5[c]	2.554	1.903	4.802	//	4.051	5.290	5.352	4.297	4.091	3.761	~5.35[h]	2.130, 2.114, 2.018, 2.000, 1.853	1.021 (d) CH_3′ 1.206 (d) CH_3 3.994 (m) CH
6[c,f]	2.61	1.93	4.83	//	//	5.30–5.45		4.40	//	3.80	5.79	2.13, 2.13, 2.04, 2.04, 1.87	0.89 (s) CMe_3 2.90 (d) CH′ 3.42 (d) CH
11[d]	2.679	1.801	3.758	//	//	3.559	//	//	3.655	3.880	—	2.034	3.385 (s) CH_3
12[d]	2.701	1.804	3.741	//	//	3.557	//	//	3.653	3.875	—	2.034	1.176 (t) CH_3 3.524 (m) CH′ // CH
13[d]	2.706	1.788	3.701	//	3.794	3.568	//	//	3.656	3.877	—	2.032	1.103 (d) CH_3′ 1.216 (d) CH_3 4.239 (m) CH
14[d]	2.737	1.830	3.732	//	3.784	3.571	//	//	3.656	3.867	—	2.034	0.879 (s) CMe_3 3.145 (d) CH′ 3.436 (d) CH

TABLE 1 (*continued*)

Compound	First-order coupling constants, Hz											Aglycon	
	$J_{3eq,3ax}$	$J_{3eq,4}$	$J_{3ax,4}$	$J_{4,5}$	$J_{5,6}$	$J_{5,NH}$	$J_{6,7}$	$J_{7,8}$	$J_{8,9}$	$J_{8,9'}$	$J_{9,9'}$	J_{vic}	J_{gem}
3[c,e]	−12.6	4.7	12.6	10.2	10.2	9.7	2.0	8.3	2.9	5.7	−12.4	—	—
4[c,f]	−12.6	4.5	12.6	10.2	[g]	[g]	[g]	~8.0	~3.0	5.9	−12.3	6.9	−9.3
5[c]	−12.5	4.6	12.5	10.2	9.8	[g,h]	2.0	8.2	2.8	5.9	−12.5	6.7	—
6[c,f]	−12.9	4.5	12.6	~10.0	[g]	9.6	[g]	[g]	~3.0	[g]	−12.6	—	−9.0
11[d]	−12.5	4.5	12.5	~10.0	~10.0	—	~1.0	8.8	[g]	6.8	−12.5	—	—
12[d]	−12.4	4.6	12.4	~9.5	[g]	—	~1.0	8.7	[g]	6.7	−12.7	6.9	−9.3
13[d]	−12.4	4.5	12.4	9.6	10.5	—	1.0	8.6	[g]	6.7	−12.7	6.2	—
14[d]	−12.6	4.5	12.7	~9.9	10.2	—	~1.0	8.5	[g]	6.3	−12.0	—	−9.0

[a]Recorded at 360 MHz in D_2O, unless otherwise stated. [b]The proton designated H-9′ resonates at higher field than H-9. [c]Measured in chloroform-*d*. [d]Multiplet in chloroform-*d*. [e]A 300-MHz, ^{1}H-n.m.r. spectrum of **3** has been published (ref. 18). [f]Recorded at 90 MHz. [g]Not assigned due to the complexity of the spectrum. [h]Overlapped by H-8 resonance signals.

TABLE II

CARBON-13 CHEMICAL SHIFTS (p.p.m.)[a] OF METHYL (ALKYL 5-ACETAMIDO-4,7,8,9-TETRA-*O*-ACETYL-3,5-DIDEOXY-α-D-*glycero*-D-*galacto*-2-NONULOPYRANOSID)ONATES

Compound	*C=O (C-1, OAc, NHAc)*	*C-2*	*C-3*	*C-4*	*C-5*	*C-6*	*C-7*	*C-8*	*C-9*	*CH_3 (NHAc)*	*CH_3 (methyl ester)*	*CH_3 (OAc)*	*Aglycon*
3	170.7, 170.4, 170.1, 169.9, 169.9, 168.0	98.7	37.6	67.2[b]	49.1	72.3[b]	68.9[b]	68.5[b]	62.2	22.9	52.5[c]	20.8, 20.5, 20.5, 20.5	52.1[c] CH_3
4	170.6, 170.3, 170.0, 169.8, 169.8, 168.3	98.4	37.8	67.2[b]	48.9	72.2[b]	69.0[b]	68.7[b]	62.1	22.7	52.3	20.8, 20.5, 20.5, 20.5	14.9 CH_3 60.4 CH_2
5	170.7, 170.4, 170.0, 169.9, 169.9, 168.7	98.5	38.2	67.2[b]	49.0	72.3[b]	68.8[b]	68.3[b]	62.2	22.8	52.2	20.8, 20.5, 20.5, 20.5	22.7 CH_3 24.3 CH_3 69.0 CH
6	170.7, 170.3, 170.0, 169.9, 169.9, 168.3	98.4	37.6	67.5[b]	48.9	72.3[b]	69.5[b]	69.2[b]	62.3	22.8	52.2	20.8, 20.5, 20.5, 20.5	26.1 CH_3 31.1 —C— 74.0 CH_2

[a]Assignments were made with the aid of refs. 26–29. [b,c] Assignments may be interchanged.

one anomer. This was further substantiated by the ^{13}C-n.m.r. spectra, which revealed only one resonance (δ ~98.5) in the anomeric region. The α configuration of the glycosidic linkage was proved unambiguously by 360-MHz, ^{1}H-n.m.r. spectroscopy of the *O*-deacetylated compounds (see below).

However, no reaction occurred with *tert*-butyl alcohol. The ^{1}H-n.m.r. spectrum showed only the presence of unreacted chloride **2**; even after 3 h, no trace of the *tert*-butyl α-glycoside **7** could be detected. This situation was also observed by Meindl and Tuppy[8], using silver carbonate or silver oxide. Probably, with tertiary aliphatic alcohols, the bulky carboxylic ester group at the anomeric centre sterically prevents the formation of the S_N2-like transition state, which appears to be involved in this type of glycosylation[14,19]. The assumption that steric inhibition occurs is supported by the fact that, under similar conditions, 2,3,4,6-tetra-*O*-acetyl-α-D-gluco- and galacto-pyranosyl bromide react smoothly to give the corresponding *tert*-butyl β-glycosides[16]. As shown by CPK space-filling models, it is unlikely that the glycerol side-chain of the Neu5Ac moiety interferes with the formation of the transition state when *tert*-butyl alcohol is used.

In silver salicylate-promoted glycosylations performed in inert solvents with per-*O*-acetylated 1,2-*cis*-glycopyranosyl halides, lowering of the alcohol concentration dramatically increases the relative yield of orthoester at the expense of the 1,2-*trans*-glycopyranoside[9,10,16]. However, with such halides as **2**, orthoester formation is impossible. When **2** was stirred overnight in benzene with 10 equivalents of neopentyl alcohol in the presence of silver salicylate, ^{1}H- and ^{13}C-n.m.r. spectroscopy (Tables I and II) indicated the almost exclusive formation of the neopentyl α-glycoside **6**. The crude product contained only traces of **8**, and neither the corresponding neopentyl β-glycoside **10** nor the elimination product **9** could be detected.

After *O*-deacetylation of the per-*O*-acetylated α-glycosides **3**–**6** in methanol, the corresponding, readily crystallisable methyl (alkyl 5-acetamido-3,5-dideoxy-α-D-

TABLE III

CHARACTERISTIC FRAGMENT-IONS A–H IN THE MASS SPECTRA OF METHYL (ALKYL 5-ACETAMIDO-3,5-DIDEOXY-α-D-*glycero*-D-*galacto*-2-NONULOPYRANOSID)ONATES[a]

Compound	*Fragments*[b]							
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
11[c]	610	566	420	298	259	205	173	342
12	624 (+14)	580 (+14)	434 (+14)	298 (0)	273 (+14)	205 (0)	173 (0)	356 (+14)
13	638 (+28)	594 (+28)	448 (+28)	298 (0)	287 (+28)	205 (0)	173 (0)	370 (+28)
14	666 (+56)	622 (+56)	476 (+56)	298 (0)	315 (+56)	205 (0)	173 (0)	398 (+56)

[a]For g.l.c.–m.s., these compounds were trimethylsilylated (see Experimental). For a full discussion of the analytical method, see ref. 21. [b]In parenthesis, the mass increments are given relative to the values for **11**. [c]Identical to a mass spectrum already published (ref. 22).

glycero-D-*galacto*-2-nonulopyranosid)onates **11–14** were obtained in total yields of 67–90%, calculated over three steps. Their structures were unambiguously proved by ^{1}H-n.m.r. spectroscopy in deuterium oxide (Table I). The observed chemical shifts for H-3*eq* and H-4 are characteristic for α-glycosidic linkages[20] (δ 2.6–2.8 for H-3*eq* and δ 3.6–3.8 for H-4). Purity and structure of **11–14** were further confirmed by g.l.c. and g.l.c.–m.s. analysis of their per-*O*-trimethylsilyl derivatives. The important, characteristic fragment-ions A–H[21–23] observed in the mass spectra are presented in Table III.

The high stereoselectivity and yields of the above reactions leading to Neu5Ac alkyl α-glycosides are noteworthy. The scope and limitations of this approach in the synthesis of sialodisaccharides are currently under investigation.

EXPERIMENTAL

Materials. — *N*-Acetyl-D-neuraminic acid (Neu5Ac) was isolated from the urine of a patient with sialuria[24]. Methyl 5-acetamido-2,4,7,8,9-penta-*O*-acetyl-3,5-dideoxy-D-*glycero*-D-*galacto*-2-nonulopyranosonate (**15**) was prepared from Neu5Ac according to Kuhn *et al.*[6]. The product was crystallised from chloroform–ethyl ether; m.p. 154–155°, $[\alpha]_D$ −4.6° (*c* 1.2, chloroform); lit.[6] m.p. 156–157°, $[\alpha]_D^{20}$ −3.3° (chloroform).

General methods. — Melting points were determined with a Meopta melting-point microscope and are uncorrected. Evaporations were conducted *in vacuo* at <40° (bath). Specific rotations were measured at ambient temperature with a Perkin–Elmer 241 polarimeter, using a 10-cm micro-cell. I.r. spectra (KBr discs) were recorded with a Perkin–Elmer Model 457 spectrophotometer. ^{1}H-N.m.r. spectra were recorded with a Varian EM-390 (90 MHz) or Bruker HX-360 (360 MHz) spectrometer, operating in the Fourier-transform mode at probe temperatures of 25°. Chemical shifts (δ) for solutions in chloroform-*d* are given relative to tetramethylsilane as internal standard. For solutions in deuterium oxide, sodium 4,4-dimethyl-4-silapentane-1-sulphonate was used (indirectly, acetone in deuterium oxide; δ 2.225). Prior to spectral analysis, solutions in deuterium oxide were exchanged three times with intermediate lyophilisation. ^{13}C-N.m.r. spectra were recorded at ~30° on a Varian CFT-20 spectrometer operating at 20 MHz in the Fourier-transform mode with complete proton-decoupling. Chemical shifts (δ) are given relative to tetramethylsilane as internal standard for solutions in chloroform-*d*. Trimethylsilylation of 1-mg samples of sugars was performed with hexamethyldisilazane and chlorotrimethylsilane in pyridine[25]. G.l.c. of per-*O*-trimethylsilyl derivatives of sugars was carried out on a Varian Aerograph 2740-30-01, equipped with a flame-ionisation detector and a glass column (2.00 m × 4.0 mm i.d.) packed with 3.8% of SE-30 on Chromosorb WHP (100–120 mesh). The injection-port and detector temperatures were 210° and 230°, respectively. The nitrogen flow-rate was 35 ml/min and the oven temperature was programmed from 200→240° at 2°/min. G.l.c.–m.s. was performed with a combined Carlo Erba GC gas chromatograph/Kratos MS 80 mass spectro-

meter/Kratos DS 55 mass-data analysis system. 70-eV Mass spectra were recorded using an ion-source temperature of 200°, an accelerating voltage of 2.7 kV, and an ionising current of 100 μA. A glass column (2.00 m × 2.0 mm i.d.) packed with 3.8% of SE-30 on Chromosorb WHP (80–100 mesh) was used. The helium flow-rate was 30 mL/min. T.l.c. was performed on silica gel (Schleicher and Schüll TLC Ready Plastic Foil FR-1500) with detection by u.v. light, or by spraying with 20% conc. sulphuric acid in methanol followed by charring at 130° for 5–10 min. The following solvents were used: *A*, chloroform–methanol (25:1); *B*, chloroform–tetrahydrofuran (10:3); *C*, ethyl acetate–2-propanol–water (2:2:1). Elemental analyses were carried out at the Institute for Organic Chemistry TNO, Utrecht, The Netherlands.

Silver salicylate. — A solution of salicylic acid (68.4 g, 50 mmol) in 96% ethanol (230 mL) was adjusted to pH 8 (wet pH-paper) with 25% aqueous ammonia. A solution of silver nitrate (81.6 g, 48 mmol) in 50% aqueous ethanol (240 mL) was added dropwise with stirring at 60–70°. The mixture was slowly cooled to room temperature after 30 min. The white precipitate was collected, washed with ethanol and ethyl ether, and dried over P_2O_5 *in vacuo*. Yield: 115.1 g (47 mmol, 98%); lit.[10] 77%.

General procedure for the preparation of the methyl (**11**), *ethyl* (**12**), *and 2-propyl* (**13**) *glycosides of methyl 5-acetamido-3,5-dideoxy-α-*D*-glycero-*D*-galacto-2-nonulopyranosonate.* — Compound **2**, freshly prepared[6] from **15** (600 mg, 1.13 mmol), was dissolved in the appropriate alcohol (10 mL), and silver salicylate (420 mg, 1.71 mmol) was added to the stirred mixture. An almost instantaneous colour change of the insoluble silver salt was observed. The suspension was stirred at room temperature in the dark for 15–30 min. The precipitate was collected over diatomaceous earth and washed with chloroform. The combined filtrates and washings were concentrated. A solution of the residue in chloroform was washed with ice-cold, 5% aqueous sodium hydrogencarbonate (twice), 5% aqueous sodium thiosulphate, and water (twice), dried (sodium sulphate), and concentrated *in vacuo*, to give compounds **3**–**5** as chromatographically homogeneous syrups (solvents *A* and *B*; see Tables I and II for spectral data). For *O*-deacetylation, each syrup was dissolved in dry methanol (20 mL) containing a catalytic amount of potassium *tert*-butoxide. The solution was stirred at room temperature until t.l.c. (solvent *C*) revealed that the reaction was complete (2–3 h). After treatment with Dowex 50W-X8(H^+) resin at 0° and evaporation, the syrupy product was crystallised from methanol–ethyl ether.

Compound **11** (339 mg, 89%) had m.p. 166–168°, $[\alpha]_D$ −5.2° (*c* 0.52, methanol); lit.[5] m.p. 160–164°; lit.[6] $[\alpha]_D^{20}$ −6.3° (methanol); i.r. data: ν_{max}^{KBr} 3450, 3240 (broad, NH, OH), 1735 ($COOCH_3$), 1645 (Amide I), and 1560 cm^{-1} (Amide II); ^{1}H-n.m.r. data: Table I; m.s. data: Table III.

Anal. Calc. for $C_{13}H_{23}NO_9$: C, 46.29; H, 6.87; N, 4.15. Found: C, 46.38; H, 6.88; N, 4.11.

Compound **12** (357 mg, 88%) had m.p. 110–111°, $[\alpha]_D$ −4.7° (*c* 0.53, methanol); lit.[12] m.p. 128–130°, $[\alpha]_D^{25}$ −3.7° (methanol); i.r. data: ν_{max}^{KBr} 3350 (broad,

NH, OH), 1755, 1730 ($COOCH_3$), 1650 (Amide I), and 1565 cm^{-1} (Amide II); ^{1}H-n.m.r. data: Table I; m.s. data: Table III.

Anal. Calc. for $C_{14}H_{25}NO_9 \cdot 0.5\ H_2O$: C, 46.66; H, 7.27; N, 3.89. Found: C, 46.27; H, 7.30; N, 4.03.

Compound **13** (348 mg, 84%) had m.p. 179–181°, $[\alpha]_D$ −3.2° (*c* 0.52, methanol); i.r. data: ν_{max}^{KBr} 3535, 3470, 3420, 3300, 3200, 3105 (NH, OH), 1765, 1740, 1723 ($COOCH_3$), 1650 (Amide I), and 1570 cm^{-1} (Amide II); ^{1}H-n.m.r. data: Table I; m.s. data: Table III.

Anal. Calc. for $C_{15}H_{27}NO_9$: C, 49.31; H, 7.45; N, 3.83. Found: C, 48.92; H, 7.44; N, 3.79.

*Methyl (neopentyl 5-acetamido-3,5-dideoxy-*α*-*D*-glycero-*D*-galacto-2-nonulopyranosid)onate* (**14**). — Compound **2**, freshly prepared[6] from **15** (600 mg, 1.13 mmol), was dissolved in 4 mL of dry benzene. Neopentyl alcohol (1.01 g, 11.46 mmol) and silver salicylate (420 mg, 1.71 mmol) were added, and the mixture was stirred at room temperature in the dark for 19 h and then processed, as described above, to give a syrup that consisted mainly of **6**, as judged by t.l.c. (solvents *A* and *B*) and ^{1}H- and ^{13}C-n.m.r. spectroscopy (Tables I and II). A solution of crude **6** in dry methanol (20 mL) containing a catalytic amount of potassium *tert*-butoxide was stirred at room temperature until t.l.c. (solvent *C*) showed that the reaction was complete (5 h). After treatment with Dowex 50W-X8(H^+) resin at 0° and evaporation, the syrupy product was crystallised from methanol–ethyl ether, to give **14** (303 mg, 67%), m.p. 165–167°, $[\alpha]_D$ −1.4° (*c* 0.49, methanol): i.r. data: ν_{max}^{KBr} 3500, 3400, 3295, 3095 (NH, OH), 1742 ($COOCH_3$), 1650 (Amide I), and 1569 cm^{-1} (Amide II); ^{1}H-n.m.r. data: Table I; m.s. data: Table III.

Anal. Calc. for $C_{17}H_{31}NO_9 \cdot 0.5\ H_2O$: C, 50.74; H, 8.02; N, 3.48. Found: C, 50.79; H, 7.83; N, 3.54.

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