New Highly Regioselective Reactions of Unprotected Sucrose. Synthesis of 2-O-Acylsucroses and 2-O-(N-Alkylcarbamoyl)sucroses

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New methodologies which lead selectively to chosen regioisomeric mono-O-acylsucroses are described. The results indicate that a selective ionization of the free sugar makes the secondary 2-OH group of the glucose moiety more nucleophilic than the primary hydroxyls. New 2-O-acylsucroses **2** and 2-O-(N-alkylcarbamoyl)sucroses **3** were thus obtained in high yields.

Introduction

Partially acylated sucrose derivatives are important compounds (i) as intermediates in sugar chemistry[1] and ii) as products of commercial significance.[2-4] As an example of the former, placement of a protective ester group at the 6-position of the glucopyranosyl part, subsequent chlorination and cleavage of the ester group provide high-intensity sweeteners.[5,6] On the other hand, pure and clearly defined amphiphilic derivatives of sucrose become of primary interest especially as surfactants for biological studies, e.g. extraction and purification of membrane proteins.[7]

Selective monoacylation of free sucrose encounter regioisomer problems owing to (i) rather similar reactivities of hydroxyls[1,8] and to (ii) easy intramolecular migrations of acyl groups in the unprotected derivatives.[8] Nevertheless acylations of the least hindered primary hydroxyls can be achieved in low or moderate yield (i) using exceptionally mild reaction conditions[1c] or the former with hindered acyl chlorides,[9] and (ii) by activation of the substrate with bulky intermediates.[10,11] Under suitable conditions, these reactions can lead to 6,1',6'-triesters, 6,6'-diesters, and 6-monoesters according to the well-established [6-OH ≥ 6'-OH > 1'-OH > secondary-OH] reactivity order of hydroxyls.[8] On the other hand, acylation of the neopentylic-like 1'-OH was performed recently by an enzymatic transesterification.[12] Complementary to these more recent studies, we have described in a preliminary communication a simple method for the preparation of 6'-O-acylsucroses.[13] As an extension of this work we have evaluated reactions of free sucrose **1** with selected acylating reagents **5-7** under reaction conditions designed to probe for regioalternating selectivity. In this paper we report full details of these studies.

Results

We expected that gradual addition of a base into a solution containing unprotected sucrose and a suitable acylating reagent, that did not react on the base, would activate selectively the more acidic hydroxyl to a more nucleophilic alkoxide. Indeed, when we dissolved 10 mmol of sucrose (**1**) and 5 mmol of 3-lauroylthiazolidine-2-thione (**5b**)[14] in anhydrous pyridine, no reaction occured. When 0.25 mmol of sodium hydride was added and the mixture was stirred at room temperature, the initial yellow-colored solution decolorized within 90 min. Acetic acid (0.5 mL) was added and the mixture subjected to our usual procedure which involves removal of the solvent and purification of esters of sucrose by silica gel column chromatography. The mixture of monoesters, isolated in a 88% yield was analyzed by GLC following conventional silylation;[15] it contained up to 80% of 2-O-lauroylsucrose (**2b**) (Table I). Compound **2b** was isolated as a single pure compound by silica gel column chromatography in a 70% yield (Table I). The same procedure was then applied to the stearoyl, hydrocinnamoyl, and 4-phenylbutyryl derivatives **5c-e**. In all cases 2-O-acylsucroses **2** were obtained in 45-64% yields along with ca. 3-10% of 3-O-acylsucroses **4**. Compounds **2** and **4** were easily purified by column chromatography.

In order to improve the scope of these acylations on a preparative scale, reactions of thiones **5f** and **5g** were

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(14) 3-Acylthiazolidine-2-thiones **5** as well as 3-acyl-5-methyl-1,3,4-thiadiazole-2(3*H*)-thiones **6** were prepared according to our previous work: Baczko, K.; Plusquellec, D. *Tetrahedron* **1991**, *47*, 3817.

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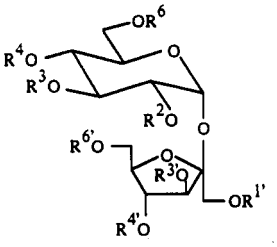
Table I. Synthesis of 2-*O*-Acylsucroses 2 and 3

		reaction conditions				isolated yields (%)	
entry	reagent[a]	solvent	base[b] (molar equiv)	time (h)	temperature (°C)	2-*O*-acylsucroses	3-*O*-acylsucroses
1	**5b**	pyridine	NaH (0.025)	1.5	rt	**2b**:70	**4b**:2
2	**5c**	pyridine	NaH (0.025)	1	rt	**2c**:64	**4c**:3.5
3	**5d**	pyridine	NaH (0.025)	3	rt	**2d**:50	**4d**:11
4	**5e**	pyridine	NaH (0.025)	2.75	rt	**2e**:45	**4e**:10
5	**5f**	DMF	NaH (0.025)	2	rt	**2f**:33	
6	**5g**	DMF	NaH (0.025)	1	rt	**2g**:49	
7	**5c**	DMF	proton sponge (1.75)	20	40	**2c**:33	**4c**:15
8	**5b**	DMF	triethylamine (5)	48	rt	**2b**:46	
9	**5c**	DMF	triethylamine (1.5)	18	40	**2c**:46	**4c**:8
10	**5d**	DMF	DABCO (1)	15	rt	**2d**:41	**4d**:5
11	**7b**	DMF	DBU (0.5)	22	rt	**3b**:30	
12	**7b**	DMF	DABCO (0.5)	8.5	rt	**3b**:33	
13	**7b**	DMF	proton sponge (0.5)	6	95	**3b**:35	
14	**7b**	DMF	anhyd C_sF (0.5)	20	rt	**3b**:42	
15	**7a**	DMF	triethylamine (1.5)	8	95	**3a**:50	
16	**7b**	DMF	triethylamine (1.5)	8	95	**3b**:52	

[a] Sucrose and reagent were used in the molar ratio of 2/1; molar equivalents of base were calculated relatively to sucrose. [b] Proton sponge: 1,8-bis(dimethylamino)naphthalene; DBU: 1,8-diazabicyclo[5.4.0]undec-7-ene; DABCO: 1,4-diazabicyclo[2.2.2]octane.

Chart I

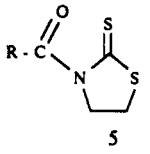


1 : $R^2 = R^3 = R^4 = R^6 = R^{1'} = R^{3'} = R^{4'} = R^{6'} = H$

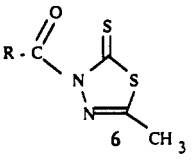
2 : $R^3 = R^4 = R^6 = R^{1'} = R^{3'} = R^{4'} = R^{6'} = H$; R^2 = CO-R

3 : $R^3 = R^4 = R^6 = R^{1'} = R^{3'} = R^{4'} = R^{6'} = H$; R^2 = CO-NH-R

4 : $R^2 = R^4 = R^6 = R^{1'} = R^{3'} = R^{4'} = R^{6'} = H$; R^3 = CO-R



5



6

R - N = C = O

7

a : R = $(CH_2)_6 - CH_3$

b : R = $(CH_2)_{10} - CH_3$

c : R = $(CH_2)_{16} - CH_3$

d : R = $(CH_2)_2 - C_6H_5$

e : R = $(CH_2)_3 - C_6H_5$

f : R = $CH(C_6H_5)_2$

g : R = $CH_2 - O$ 

performed in anhydrous dimethylformamide which is a more convenient solvent for sucrose. However, in the presence of a catalytic amount of sodium hydride, and using the hindered reagent **5f**, 2-*O*-(diphenylacetyl)sucrose (**2f**) is produced in a lower yield (33%). But, using the less hindered (naphth-2-oxyacetyl) derivative **5g**, compound **2g** was successfully obtained in a higher 49% yield. In all experiments described thus far, sodium hydride was employed as an initiator. It was also found that the anion of thiazolidine-2-thione, used in catalytic amounts (0.05 molar equiv) gave the same results as obtained when sodium hydride was used.

To make the synthesis more practical, we examined also the use of weakly nucleophilic bases in dimethylformamide. The data observed with 1,8-bis(dimethylamino)naphthalene (proton sponge) indicated that both the overall yields and the regioselectivity were lower, 3-*O*-acylsucroses being obtained in larger amounts. On the other hand, when reactions were carried out in the presence of triethylamine or 1,4-diazabicyclo[2.2.2]octane (DABCO), acylations occured readily and 2-*O*-acylsucroses **2b–d** were isolated in 41–46% yields. The latter is to be compared with our previous results[13] which showed that acylation of free sucrose with 3-acyl-5-methyl-1,3,4-thiadiazole-2(3*H*)-thiones **6**, in the presence of DABCO at lower temperatures, occured selectively at the 6′-OH of the fructosyl moiety.

Encouraged by these results, we extended the repertoire of acylations to the synthesis of carbamates by selective additions of sucrose to alkyl isocyanates. In order to enhance the selectivity, reactions were performed in anhydrous dimethylformamide in the presence of selected bases as presented in Table I. The data indicates that anhydrous cesium fluoride and triethylamine gave higher overall yields and regioselectivity than DABCO, DBU, and proton sponge. When the sucrose acylations were carried out at 95 °C in the presence of 3 molar equiv of triethylamine for 8 h, monoalkyl carbamates of sucrose were obtained in high yield. 2-*O*-Acylsucroses **3a** and **3b** were found to be isolated as single pure compounds by column chromatography in 50 and 52% yields, respectively. The position of the acyl group on sucrose was determined by ^{13}C NMR following the general method of Yoshimoto et al.[16] and was corroborated by LC-ISP mass spectrometry.[17] It is worth mentioning that the secondary 2-OH of sucrose was more reactive than the primary ones when the described conditions were employed. The highly selective synthesis of compounds **2** and **3** is, to our knowledge, the first such example to be reported.

Discussion

The results reported above show that a reasoned choice of acylation conditions is a decisive element in determining the regioselectivity of reactions. An explanation for

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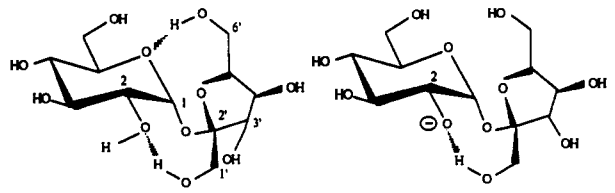
Chart II



A : Intramolecular hydrogen bonds in the crystallized sucrose 1

B : 2-oxyanion of sucrose

Table II. Acylation of Sucrose in the Presence of Sodium Hydride

entry	reagent (0.5 equiv)	base (molar equiv)[a]	conditions	isolated yield, % overall	2-O-acyl	6-O-acyl
1	**5g**	NaH (0.0125)	1 h at rt in DMF	70	50	3
2	**6g**	NaH (0.5)	4 h at rt in DMF	78	9	23
3	**6g**	NaH (1)	4 h at rt in DMF	40	3	24

[a] Molar equiv based on sucrose.

regioselective base-catalyzed acylation of free sucrose should account not only for sterical factors but also for relative acidities of the hydroxyl groups.[18] The least hindered primary hydroxyl groups of sucrose should therefore be more nucleophilic as well as the 2- and 3'-secondary hydroxyls owing to the field effects of the acetal oxygen atoms attached to the anomeric carbons C-1 and C-2'. Nevertheless, the enhanced reactivity of the 2-OH compared with the others is presumably a result of other structural effects. The structure of sucrose in the crystalline state is well established[19] and it was found that the overall structure is determined by two intramolecular hydrogen bounds as depicted in Chart II. The conformational behavior of sucrose in water and in organic solvents is still controversial,[20-24] but most chemists accept that the 2-oxygen of the glucopyranose moiety in sucrose acts as an hydrogen bonding acceptor even in polar aprotic solvents.[20-23] The 2-OH will therefore be the most acidic[25] and activation of the substrate with a catalytic amount of sodium hydride will lead to the stabilized and highly nucleophilic 2-oxyanion (Chart II).[26] This alkoxide then reacts with the esterifying agent to give the 2-*O*-acyl derivative and the ambident anion of thiazolidine-2-thione. The latter should be basic enough to continue the activation process, and we have experimentally verified that it may be used as a substitute for NaH in the initiation step. In other respects, the ratio of initiator to substrate has to be maintained as low as possible in order to avoid ionization of several hydroxyls. Indeed when 1 molar equiv of NaH was used (Table II), regioselectivity decreased and the main product became the 6-*O*-acyl derivative.

On the other hand, the type of acylating reagent dramatically directs the selectivity of the reaction. Indeed our results show that 2-O-acylation of sucrose has to be performed in such a way that no electrophilic acylium intermediates are produced. In other words, 3-acylthiazolidine-2-thiones **5** appear to be more efficient in these reactions than 3-acyl-5-methyl-1,3,4-thiadiazole-2(3*H*)-thiones **6** which easily lead to electrophilic ion-pairs when associated with organic base. Additions of free sucrose to alkyl isocyanates in the presence of triethylamine could be rationalized in the same way.

Partial O-alkylation of sucrose with benzyl bromide under Kuhn conditions was earlier found by Reinfeld to proceed selectively and 2-*O*-benzylsucrose was thus isolated laboriously in a 32% yield.[27] Nevertheless, to the best of our knowledge, a such selectivity towards a secondary hydroxyl of sucrose was not attainable to date in acylation reactions.

In conclusion, employing the methodologies described herein, highly regioselective acylations of unprotected sucrose were performed at the secondary 2-hydroxyl group. Prior to our work, only a few of 2-*O*-acylsucroses have been laboriously and unambigously identified in complex mixtures. Since sucrose esters and carbamates of fatty acids are nonionic mild surfactants, the suitability of compounds obtained herein for extraction of integral membrane proteins is in progress and will be reported.

Experimental Section

General Methods. All melting points were determined using a Reichert apparatus and are uncorrected. Elemental analyses were made by the Service Central d'Analyse du CNRS, Vernaison (France) and by the Service de Microanalyse de l'ENSCR, Rennes (France). Thin-layer chromatography (TLC) was performed on Merck 60F254 silica gel unactivated plates. The UV light and a solution of 5% H_2SO_4 in ethanol followed by heating at 140–150 °C were used to develop the plates. The relative ratios in mixed chromatography solvents refer to the volume/volume ratio. For column chromatography, Merck 60H (5–40 μm) silica gel was used. GC analyses were performed on a VEGA GC 6000 gas chromatograph using nitrogen as carrier and (1) a capillary SGE column (12 m × 0.33 mm i.d.) coated with BP1, film thickness 0.5 μm; (2) an Altech column (15 m × 0.32 mm i.d.) coated with OV 1, film thickness 0.5 μm. HPLC analyses were performed using a Spectra Physics SP 8800 apparatus, a LDC Spectromonitor III detector, and a 250 × 4.6 mm Spherisorb 5W column. Peak areas were obtained by using a Spectra Physics SP 4290 computing integrator. Optical rotations were measured using a Polartronic D polarimeter. IR spectra were taken using HCB (hexachlorobutadiene) on a Pye Unicam SP3-200 spectrophotometer. ^1H NMR spectra were recorded at 89.5 MHz using a JEOL FX90 Q spectrometer. ^{13}C NMR spectra were determined at 22.5 or at 75 MHz using a JEOL FX 90 Q or a Bruker AM 300 spectrometer. Chemical shifts are reported in ppm downfield from tetramethylsilane (TMS). Electron impact mass spectra (EI) were determined on a Varian MAT 311 spectrometer at 70 eV. Molecular masses are given in atomic mass units (amu), followed by percent intensity relative to the most abundant ion. All reagents were of commercially quality and were purchased from Janssen Chimica or Aldrich Chemie. Solvents were purified according to general procedures, and reactions were performed under nitrogen atmosphere.

General Procedures for the Synthesis of 2-*O*-Acylsucroses. Method A. Sucrose (1) (3.4 g, 10 mmol) was dissolved in 80 mL of anhydrous pyridine at 80 °C for 10 min. The solution was allowed to cool at room temperature and the appropriate 3-acylthiazolidine-2-thione **5** (5 mmol) was added followed by sodium hydride (10 mg, 0.25 mmol) in one portion. The mixture was stirred at the same temperature until decolorization of the yellow solution had occured (1–3 h). The reaction was monitored by TLC using chloroform, methanol, acetic acid, and water (37:

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8:4:1). After addition of acetic acid (0.5 mL), the solvent was removed in vacuo at 35–40 °C. The solid residue was then partitioned between a phosphate buffer (pH 7; 20 mL) and a mixture containing ethyl acetate and *n*-butanol (1/1, v/v; 40 mL). The aqueous phase was extracted twice with the same mixture (2 × 10 mL) and the combined organic layers were washed with water (3 × 10 mL) and concentrated. The residue was subjected to column chromatography.

2-*O*-Lauroylsucrose (2b) and 3-*O*-Lauroylsucrose (4b). The reaction of 3-lauroylthiazolidine-2-thione (**5b**) with sucrose (1) for 90 min after purification by column chromatography, eluting with a step ethyl acetate/methanol gradient that varied from 5 to 7.7 and finally to 10% methanol, gave **2b** (R_f 0.51) and **4b** (R_f 0.62) in yields of 70% and 2%, respectively.

2b: white powder when crystallized from ethyl acetate; mp 156–159 °C; $[\alpha]^{20}_D$ +50° (*c* = 1, methanol); IR (hexachlorobutadiene) 3390 (OH), 1725 (C=O) cm^{-1}; ^{1}H NMR (DMSO-d_6, 89.5 MHz) δ 0.88 (3 H, t), 1.27 (16 H, m), 1.47 (2 H, m), 2.30 (2 H, t), 2.80–4.40 (13 H, m), 4.40–5.20 (7 H, m), 5.35 (1 H, d, *J* = 3.5 Hz); ^{13}C NMR (DMSO-d_6, 22.5 MHz) δ 13.94 (CH_3), 22.06, 24.22, 28.50, 28.69, 28.77, 28.91, 28.99, 31.27 and 33.57 (CH_2), 60.36 (C_6), 61.19 ($C_{1'}$), 62.19 ($C_{6'}$), 69.84 (C_4), 70.11 (C_3), 72.57 (C_5), 72.93 (C_2), 73.76 ($C_{4'}$), 75.34 ($C_{3'}$), 82.59 ($C_{5'}$), 88.69 (C_1), 104.24 ($C_{2'}$), 172.79 (C=O). Anal. Calcd for $C_{24}H_{44}O_{12}$: C, 54.95; H, 8.45. Found C, 55.30; H, 8.46.

4b: amorphous product; ^{13}C NMR (DMSO-d_6, 22.5 MHz) δ 13.90 (CH_3), 22.08, 24.52, 28.48, 28.72, 29.02, 31.32, 33.89 (CH_2), 60.19 (C_6), 62.20 ($C_{6'}$ and $C_{1'}$), 67.70 (C_4), 69.68 (C_2), 72.55 (C_5), 74.28 ($C_{4'}$), 75.58 (C_3), 77.02 ($C_{3'}$), 82.65 ($C_{5'}$), 91.51 (C_1), 104.13 ($C_{2'}$), 172.53 (C=O).

2-*O*-Stearoylsucrose (2c) and 3-*O*-Stearoylsucrose (4c). Using the same procedure, we obtained after workup compounds **2c** (yield 64%) and **4c** (yield 3.5%).

2c: mp 165–178 °C from ethyl acetate; $[\alpha]^{20}_D$ +58° (*c* = 1, methanol); IR (hexachlorobutadiene) 3380 (OH) and 1725 (C=O) cm^{-1}; ^{1}H NMR (DMSO-d_6, 89.5 MHz) δ 0.89 (3 H, t), 1.29 (30 H, s), 2.34 (2 H, t), 2.80–4.50 (13 H, m), 4.40–5.20 (7 H, m), 5.35 (1 H, d, *J* = 3.0 Hz); ^{13}C NMR (DMSO-d_6, 22.5 MHz) δ 13.85 (CH_3), 22.00, 24.17, 28.48, 28.61, 28.99, 31.21, 33.51 (CH_2), 60.30 (C_6), 61.14 ($C_{1'}$), 62.17 ($C_{6'}$), 69.78 and 70.05 (C_3 and C_4), 72.52 (C_5), 72.90 (C_2), 73.71 ($C_{4'}$), 75.31 ($C_{3'}$), 82.60 ($C_{5'}$), 88.64 (C_1), 104.18 ($C_{2'}$), 172.40 (C=O). Anal. Calcd for $C_{30}H_{56}O_{12}$: C, 59.19; H, 9.27; O, 31.54. Found C, 58.91; H, 9.02; O, 31.66.

4c: amorphous powder; ^{13}C NMR (DMSO-d_6, 22.5 MHz) δ 13.85 (CH_3), 22.00, 24.17, 28.48, 28.61, 28.99, 31.21, 33.51 (CH_2), 60.09 (C_6), 62.14 ($C_{1'}$ and $C_{6'}$), 67.62 (C_4), 69.59 (C_2), 72.47 (C_5), 74.25 ($C_{4'}$), 75.53 (C_3), 76.91 ($C_{3'}$), 82.60 ($C_{5'}$), 91.45 (C_1), 104.10 ($C_{2'}$), 172.47 (C=O).

2-*O*-Hydrocinnamoylsucrose (2d) and 3-*O*-Hydrocinnamoylsucrose (4d). The reaction of sucrose (1) with thione **5d** within 3 h at room temperature gave esters **2d** (yield 50%, R_f 0.32) and **4d** (yield 11%, R_f 0.42).

2d: amorphous compound; $[\alpha]^{20}_D$ +52° (*c* = 1, methanol); IR (hexachlorobutadiene) 3350 (OH) and 1730 (C=O) cm^{-1}; ^{1}H NMR (DMSO-d_6, 89.5 MHz) δ 2.57 (4 H, m), 2.88–4.57 (13 H, m), 4.82–5.20 (7 H, m), 5.39 (1 H, d, *J* = 3 Hz), 7.31 (5 H, m); ^{13}C NMR (DMSO-d_6, 22.5 MHz) δ 30.07, 35.19 (CH_2), 60.38 (C_6), 61.28 ($C_{1'}$), 62.33 ($C_{6'}$), 69.86 and 70.11 (C_3 and C_4), 72.60 (C_5), 73.14 (C_2), 73.85 ($C_{4'}$), 75.47 ($C_{3'}$), 82.62 ($C_{5'}$), 88.74 (C_1), 104.37 ($C_{2'}$), 126.02, 128.21, 128.35, 140.56 (arom), 172.09 (C=O); MS (heptaacetate, EI, 70 eV) *m/z* (rel inten) 768 M$^{+\cdot}$ (not observed), 421 (21.40, (M − 347)$^+$, HRMS calcd for $C_{21}H_{25}O_9$ 421.14985, found 421.1503), 331 (62.18, (M − 437)$^+$, HRMS calcd for $C_{14}H_{19}O_9$ 331.10289, found 331.1017), 361 (2.86), 301 (4.88), 271 (4.08), 241 (1.74), 229 (1.43), 211 (66.95), 169 (100), 133 (34.68), 109 (60.71), 105 (28.12), 91 (17.22), 43 (80.94); Anal. Calcd for heptaacetate $C_{35}H_{44}O_{19}\cdot H_2O$: C, 53.43; H, 5.89. Found C, 53.82; H, 5.80.

4d: amorphous powder; $[\alpha]^{20}_D$ +52° (*c* = 1, methanol); ^{13}C NMR (DMSO-d_6, 22.5 MHz) δ 30.24, 35.30 (CH_2), 60.06 (C_6), 62.17 ($C_{6'}$ and $C_{1'}$), 67.56 (C_4), 69.57 (C_2), 72.47 (C_5), 74.25 ($C_{4'}$), 75.96 (C_3), 76.88 ($C_{3'}$), 82.62 ($C_{5'}$), 91.45 (C_1), 104.10 ($C_{2'}$), 125.94, 128.18, 128.29, 140.73 (arom), 171.85 (C=O); MS (trimethylsilyl derivative, EI, 70 eV) *m/z* (rel inten) 978 M$^{+\cdot}$ (not observed), 511 (2.76, (M − 467)$^+$, HRMS calcd for $C_{24}H_{43}O_6Si_3$ 511.23672, found 511.2378), 451 (9.37, (M − 527)$^+$, HRMS calcd for $C_{18}H_{43}O_5Si_4$ 451.21874, found 451.2187), 437 (16.41), 361 (100), 271 (11.20), 217 (56.88), 204 (2.24), 191 (5.77), 133 (5.40), 132 (1.78), 103 (13.70), 73 (48.19).

2-*O*-(4-Phenylbutyryl)sucrose (2e) and 3-*O*-(4-Phenylbutyryl)sucrose (4e). Esters **2e** (R_f 0.32) and **4e** (R_f 0.42) were obtained in yields of 45% and 10%, respectively.

2e: white powder; $[\alpha]^{20}_D$ +53° (*c* = 1, methanol); IR (hexachlorobutadiene) 3350 (OH) and 1730 (C=O) cm^{-1}; ^{13}C NMR (DMSO-d_6, 22.5 MHz) δ 26.09, 33.08, 34.33 (CH_2), 60.38 (C_6), 61.25 ($C_{1'}$), 62.22 ($C_{6'}$), 69.86 and 70.14 (C_3 and C_4), 72.60 (C_5), 73.03 (C_2), 73.77 ($C_{4'}$), 75.36 ($C_{3'}$), 82.59 ($C_{5'}$), 88.69 (C_1), 104.27 ($C_{2'}$), 125.79, 128.32, 141.51 (arom), 172.61 (C=O); MS (heptaacetate, EI, 70 eV) *m/z* (rel inten) 782 M$^{+\cdot}$ (not observed), 435 (11.45, (M − 347)$^+$, HRMS calcd for $C_{22}H_{27}O_9$ 435.16459, found 435.1660), 331 (40.76, (M − 451)$^+$, HRMS calcd for $C_{14}H_{19}O_9$ 331.10289, found 331.1017), 289 (0.11), 271 (1.15), 229 (0.94), 211 (62.52), 169 (57.90), 147 (100), 109 (34.39), 104 (8.04), 91 (14.66), 43 (71.21), 42 (1.01). Anal. Calcd for heptaacetate $C_{36}H_{46}O_{19}\cdot 2H_2O$: C, 52.81; H, 6.10. Found C, 53.13; H, 6.04.

4e: amorphous compound; ^{13}C NMR (DMSO-d_6, 22.5 MHz) δ 26.53, 33.32 and 34.27 (CH_2), 60.14 (C_6), 62.20 ($C_{6'}$ and $C_{1'}$), 67.62 (C_4), 69.62 (C_2), 72.52 (C_5), 74.28 ($C_{4'}$), 75.66 (C_3), 76.93 ($C_{3'}$), 82.65 ($C_{5'}$), 91.51 (C_1), 104.16 ($C_{2'}$), 125.77, 128.29, 128.37 and 141.62 (arom), 172.34 (C=O); MS (trimethylsilyl derivative, EI, 70 eV) *m/z* (rel inten) 992 M$^{+\cdot}$ (not observed), 525 (3.68, (M − 467)$^+$, HRMS calcd for $C_{25}H_{45}O_6Si_3$ 525.25237, found 525.2517), 451 (13.56, (M − 541)$^+$, HRMS calcd for $C_{18}H_{43}O_5Si_4$ 451.21874, found 451.2187), 437 (13.96), 361 (100), 271 (6.40), 217 (40.93), 204 (1.04), 191 (2.98), 133 (1.55), 132 (1.04), 103 (9.40), 73 (27.69).

Method B. Sucrose 1 (3.4 g, 10 mmol) and (diphenylacetyl)-thiazolidine-2-thione (**5f**) were dissolved in anhydrous dimethylformamide. Sodium hydride (10 mg, 0.25 mmol) was added at room temperature, and the mixture was stirred at the same temperature. The reaction was monitored by TLC using ethyl acetate, methanol, acetic acid, and water (40:8:1.6:0.4) for 2 h and then acetic acid (0.5 mL) was added. Removal of solvent at reduced pressure followed by column chromatography of the residue (ethyl acetate/MeOH; step gradient 19:1 and then 9:1, v/v) afforded **2f** (0.88 g, 33%) which could be further purified by crystallization from acetone.

2f: mp 198–199 °C; $[\alpha]^{20}_D$ +57° (*c* = 0.82, methanol); IR (hexachlorobutadiene) 3380 (OH) and 1725 (C=O) cm^{-1}; ^{13}C NMR (D_2O + 1% 1,4-dioxane, 22.5 MHz) δ 57.59 (CH), 61.03 (C_6), 61.36 ($C_{1'}$), 63.15 ($C_{6'}$), 70.33 (C_4), 71.38 (C_3), 73.25 (C_5), 73.98 (C_2), 74.67 ($C_{4'}$), 76.12 ($C_{3'}$), 82.30 ($C_{5'}$), 90.42 (C_1), 104.73 ($C_{2'}$), 128.37, 128.59, 129.43, 129.57, 129.81, 138.67 and 139.02 (arom), 174.80 (C=O). Anal. Calcd for $C_{26}H_{32}O_{12}$: C, 58.20; H, 6.01. Found C, 58.00; H, 6.00.

2g was obtained by the previously described procedure. Purification by column chromatography gave **2g** (1.26 g, 49%) as a white powder: mp 172–184 °C; $[\alpha]^{20}_D$ +51° (*c*=1, methanol); IR (hexachlorobutadiene) 3400 (OH), 1740 (C=O) cm^{-1}; ^{13}C NMR (D_2O + 1% 1,4-dioxane, 22.5 MHz) δ 61.17 (C_6), 62.42 ($C_{1'}$), 63.12 ($C_{6'}$), 65.59 (OCH_2), 73.33 (C_4), 71.35 (C_3), 73.30 (C_5), 74.14 (C_2), 74.79 ($C_{4'}$), 76.83 ($C_{3'}$), 82.32 ($C_{5'}$), 90.40 (C_1), 104.86 ($C_{2'}$), 108.22, 118.76, 125.01, 127.37, 127.72, 128.32, 129.92, 130.51, 134.77, 155.70 (arom), 170.85 (C=O). Anal. Calcd for $C_{24}H_{30}O_{13}$: C, 54.75; H, 5.70. Found C, 54.66; H, 5.83.

Method C. Sucrose (1) (3.4 g, 10 mmol) was dissolved in 30 mL of anhydrous dimethylformamide. 3-Lauroylthiazolidine-2-thione (**5b**) (5 mmol) was added in one portion followed by triethylamine (100 mmol, 14 mL) via syringe. The mixture was then stirred at room temperature for 48 h and worked up as described in the above procedure. 2-*O*-Lauroylsucrose (**2b**) could thus be obtained in 46% yield.

General Procedure for the Synthesis of 2-*O*-(*N*-Alkylcarbamoyl)sucroses 3. Sucrose (3.1 g, 9 mmol) was dissolved in anhydrous DMF (30 mL) at 80 °C for 5 min. The solution was cooled at 5 °C and heptyl- or undecyl isocyanate[28] (3 mmol) followed by triethylamine (9 mmol, 1.26 mL) were added via syringe. The mixture was stirred at 95 °C for 8 h under dry nitrogen, and the reaction was monitored by TLC using chloroform, methanol, acetic acid, and water (37:8:4:1). Acetic acid

(28) Allen, C. F. H.; Bell, A. *Organic Syntheses*; Wiley: New York, 1955; Collect. Vol. III, p 846.

(2 mL) was added and the solvent was removed under reduced pressure. To the residue were added *n*-butanol (30 mL) and a phosphate buffer at pH 7 (20 mL). The aqueous layer was extracted twice with *n*-butanol (2 × 10 mL), and the combined extracts were washed with water and concentrated. The residue was purified twice by column chromatography using (i) ethyl acetate and methanol (15:1) and (ii) dichloromethane methanol (5:1) to give **3a** (0.72 g; 50%) and **3b** (0.84 g; 52%). A sample of each compound was analyzed after conventional silylation, by GLC analysis on an Altech OV1 column (initial temperature, 270 °C, 5 s; final temperature, 305 °C; rate, 2 deg/min) showing highly purified (>99%) carbamates.

2-*O*-(*N*-Heptylcarbamoyl)sucrose (3a). Hygroscopic compound: $[\alpha]^{20}_D$ +55.8° (*c* = 1, ethanol); IR (hexachlorobutadiene) 3400 (OH) and 1700 (C=O) cm^{-1}; ^{13}C NMR (DMSO-d_6 22.5 MHz) δ 13.90 (CH_3), 22.03, 26.23, 28.37, 29.34 and 31.18 (CH_2), 60.25 (C_6), 60.71 ($C_{1'}$), 61.79 ($C_{6'}$), 69.95 (C_4), 70.27 (C_3), 72.52 (C_5), 73.12 (C_2), 73.52 ($C_{4'}$), 74.90 ($C_{3'}$), 82.49 ($C_{5'}$), 88.99 (C_1), 104.18 ($C_{2'}$), 156.08 (C=O); MS (trimethylsilyl derivative, EI, 70 eV) *m/z* (rel inten) 987 $M^{+\cdot}$ (not observed), 520 (19.84, $(M-467)^+$, HRMS calcd for $C_{23}H_5NO_6Si_3$ 520.29457; found 520.2952), 451 (6.68, $(M-536)^+$, HRMS calcd for $C_{18}H_{43}O_5Si_4$ 451.21874; found 451.2187), 437 (5.51), 361 (44.45), 298 (43.33), 289 (33.94), 271 (9.26), 217 (45.52), 204 (1.81), 191 (7.08), 133 (3.65), 132 (2.12), 103 (21.69), 73 (100.00).

2-*O*-(*N*-Undecylcarbamoyl)sucrose (3b). White powder crystallized from 2-propanol/2-propyl acetate: mp 162–164 °C; $[\alpha]^{20}_D$ +60.5° (*c* = 1, ethanol); IR (hexachlorobutadiene) 3400 (OH) and 1700 (C=O) cm^{-1}; ^{13}C NMR (DMSO-d_6 22.5 MHz) δ 13.88 (CH_3), 22.06, 26.36, 28.71, 29.02, 29.37, 31.29 (CH_2), 60.22 (C_6), 60.71 ($C_{1'}$), 61.77 ($C_{6'}$), 69.95 (C_4), 70.27 (C_3), 72.52 (C_5), 73.12 (C_2), 73.52 ($C_{4'}$), 74.96 ($C_{3'}$), 82.49 ($C_{5'}$), 88.99 (C_1), 104.21 ($C_{2'}$), 156.11 (C=O); MS (trimethylsilyl derivative, EI, 70 eV) *m/z* (rel inten) 1043 $M^{+\cdot}$ (not observed), 1028 (0.73; $(M-CH_3)^+$; HRMS calcd for $C_{44}H_{98}NO_{12}Si_7$ 1028.54734; found 1028.5465), 576 (64.45, $(M-467)^+$, HRMS calcd for $C_{27}H_{58}NO_6Si_3$ 576.35717; found 576.3581), 451 (27.02; $(M-592)^+$; HRMS calcd for $C_{18}H_{43}O_5Si_4$ 451.21874; found 451.2187), 437 (9.01), 361 (40.55), 354 (24.73), 289 (25.99), 271 (10.65), 217 (55.09), 204 (3.17), 191 (5.08), 133 (3.97), 132 (2.95), 103 (23.99), 73 (100.00).

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Supplementary Material Available: ^{13}C NMR spectra for all new compounds reported (13 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.