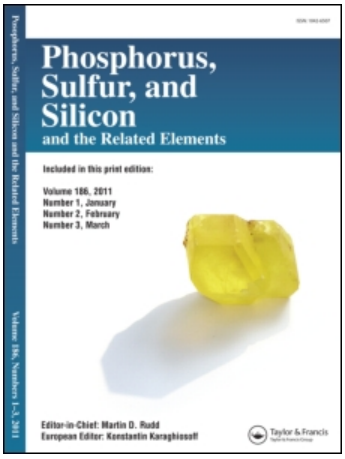

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The Synthesis and Some Chemical Properties of New 1,2:5,6-DI-*O*-Isopropylidene-α -D-Glucofuranose Hydrophosphoryl Derivatives

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The Synthesis and Some Chemical Properties of New 1,2:5,6-DI-*O*-Isopropylidene-α-D-Glucofuranose Hydrophosphoryl Derivatives

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*Methods for the synthesis of major monosaccharide hydrophosphoryl derivatives have been developed with the phosphorylation of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (diacetoneglucose) as an example. The study of their chemical transformations has been launched.*

Keywords 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (diacetoneglucose); diastereomers; hydrophosphoryl compounds; phosphorylation; phosphorylating agent

The first experiments on the synthesis of monosaccharide phosphites, including the corresponding hydrophosphoryl derivatives,[1–3] were performed earlier in our laboratory. The present work deals with the development of our earlier studies. The aim of this work is to study the synthesis and chemical properties of phosphorus-containing derivatives of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose in whose molecules the hydrophosphoryl group is bound to alkyl or aryl substituents.

RESULTS AND DISCUSSION

Hydrophosphoryl derivatives of diacetoneglucose were synthesized by a two-step method. First, the monosaccharide was treated with alkylphosphorous and phenylphosphorous acid dichlorides (at a molar reagent ratio of 1:1.1) in the presence of pyridine (Scheme 1).

Note that, according to ^{31}P NMR data, these reactions usually are accompanied by the formation of neutral esters of phosphorous or

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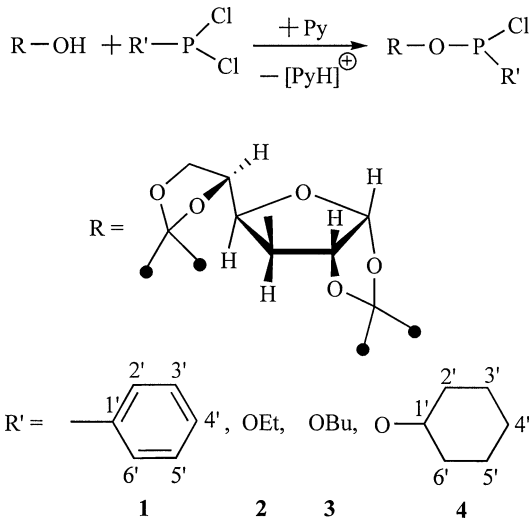
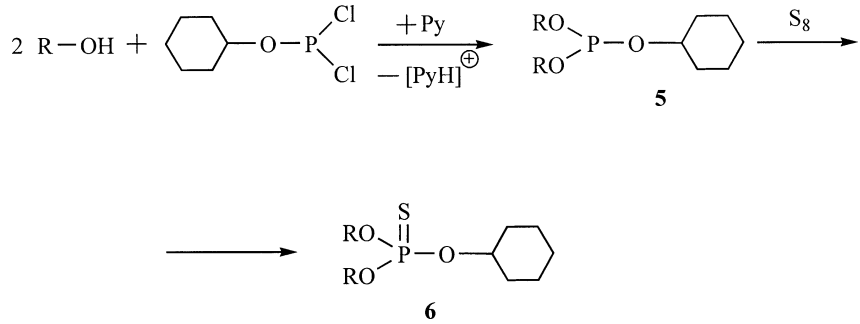


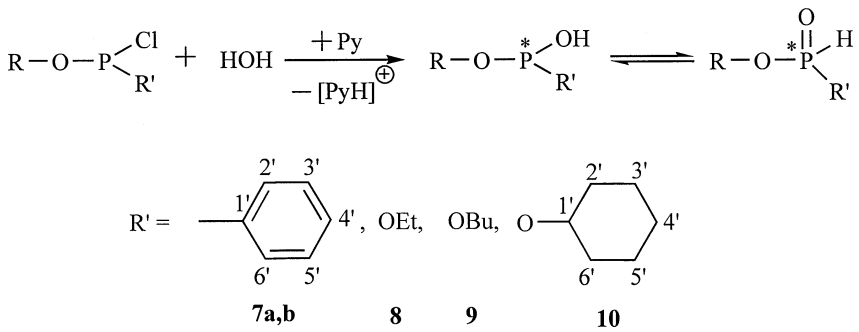
SCHEME 1 Synthesis of acid monochlorides.

phenylphosphorous acid, whose molecules contain two diacetoneglucose moieties. This conclusion was confirmed by the counter synthesis of a similar ester (Scheme 2).

The spectral parameters of the impurity formed in the synthesis of acid monochloride **4** and of the counter-synthesis product **5** were found to be identical. Because the reaction product **5** was labile, we converted it to the corresponding thionophosphate **6**. The structure of compound **6** was supported by ^{1}H, ^{13}C, and ^{31}P NMR spectroscopy, as well as by cryoscopy and elemental analysis.



SCHEME 2 Synthesis of neural ester of phosphorous acid.



SCHEME 3 Hydrolysis of acid monochlorides.

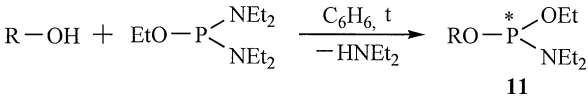
Acid monochlorides **1–4**, without additional purification, were hydrolyzed in the presence of pyridine; the process resulted in the formation of the target hydrophosphoryl compounds (Scheme 3).

Their structures were supported by ^{1}H, ^{13}C, and ^{31}P NMR spectroscopy. In the ^{31}P NMR spectra, two doublets were observed at 5–9 ppm for phosphites and at 26.5/28.2 ppm for phosphonite **7** with coupling constants of 500–700 Hz. The strongly pronounced anisochronicity in the ^{31}P NMR spectra (Figure 1) and in the signals of some ^{1}H and ^{13}C atoms indicates that the synthesized hydrophosphoryl compounds are formed as two diastereomers. The diastereomer ratio in the reaction products varies as follows: 1:1 (**8**), 1:1.15 (**9**), 1:1.2 (**10**), and 1:2.3 (**7**). It is notable that the introduction of a phosphoric group with the rigid phenyl radical into the carbohydrate molecule allows the best differentiation of two diastereomeric groups.

Compound **8** also was obtained using phosphorous acid amides.[4]

At the first step, the carbohydrate was phosphorylated with phosphorous acid amides. Tetraethyldiamidophosphorous acid ethyl ester $(Et_2N)_2POEt$ was used as a phosphorylating agent (Scheme 4).

The reaction yielded a mixture of two diastereomers in similar proportions, as was attested by anisochronicity in the ^{31}P NMR spectra, showed two singlets with chemical shifts of 142.68 and 143.09 ppm corresponding to product **11**.



11

SCHEME 4 Sugar phosphorylation wing tetraethyldiamidophosphorous acid.

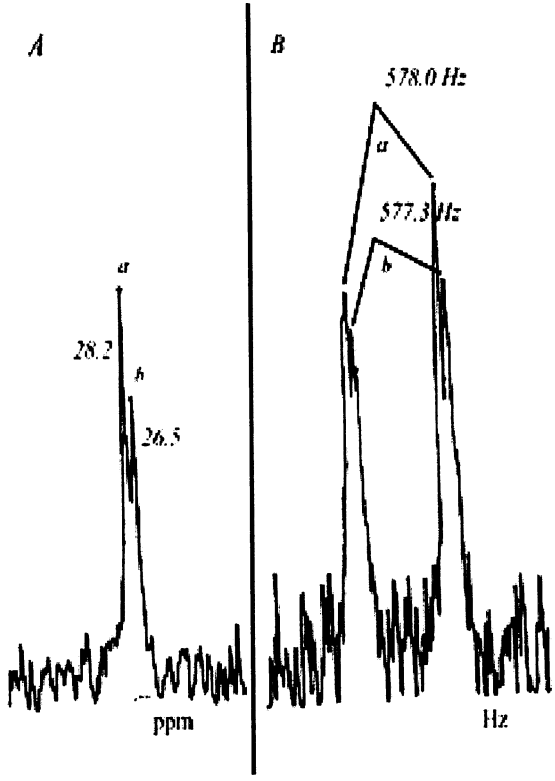
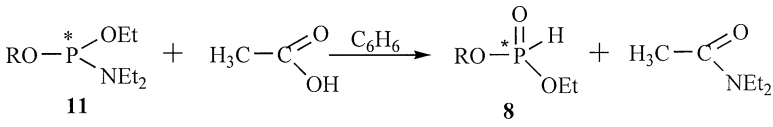


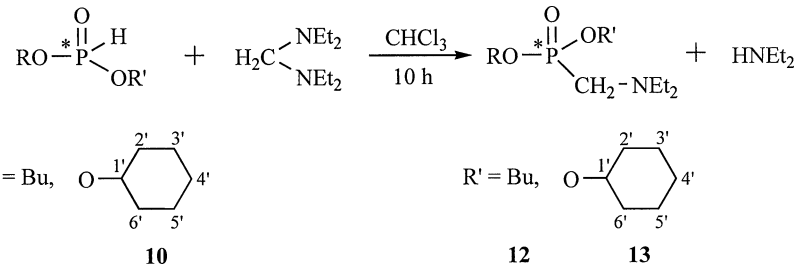
FIGURE 1 Anisochronicity in the ^{31}P NMR spectrum of 3-*O*-phenylphosphonite-1,2;5,6-di-*O*-isopropylidene-α-D-glucofuranose (**7a**,**b**) in $CHCl_3$: (a) The spectrum was recorded with suppression of the effect of the P–H bond protons; (b) the spectrum was recorded with account for the effect of the P–H bond protons.

The second step included the acidolysis of the adduct obtained. Acetic acid (0.9 eq.) was added to 1 eq. of sugar **11**, without its preliminary isolation (Scheme 5).

Product **8** was purified by column chromatography. Its structure was supported by ^1H, ^{13}C, and ^{31}P NMR spectroscopy and elemental



SCHEME 5 Acidolysis of sugar **11**.



9 **10** **12** **13**

SCHEME 6 Hydrophosphoryl derivatives **9** and **10** in Kabachnick–Fields reaction.

analysis. The structure of product **8** completely corresponds to that of the hydrophosphoryl derivative prepared by the acid "chloride" method.

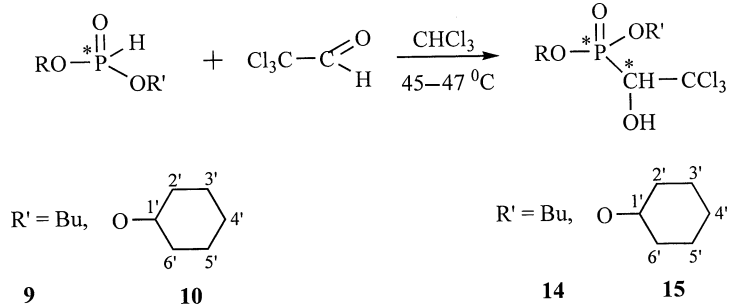
The second part of our work was devoted to the study of some chemical properties of diacetoneglucose hydrophosphoryl derivatives. Compounds **9** and **10** (which contain a more bulky cyclohexyl radical) were used as starting materials. The hydrophosphoryl derivatives were introduced into the Kabachnik–Fields and Abramov reactions.

In the Kabachnik–Fields reaction, bis(diethylamino)methane was used as electrophilic agent (Scheme 6).

The reactions were conducted at room temperature for 10 h and controlled by TLC and ^{31}P NMR spectroscopy. Compounds **12–13** were formed as two diastereomers in similar proportions.

The Abramov reaction was conducted with chloral. It proceeded more slowly than the Kabachnik–Fields reaction (Scheme 7).

The reaction proceeded in the presence of a large excess of chloral (2.5 eq. per 1 eq. of sugar) at 45–47°C (in a glycerin bath) for 5 (compound **9**) and 7 h (compound **10**). The product yield was no more than 75%.



9 **10** **14** **15**

SCHEME 7 Hydrophosphoryl derivatives **9** and **10** in an Abramov reaction.

Compounds **14–15** were purified by column chromatography; they represent mixtures of four diastereomers. Their structures were supported by ^{1}H, ^{13}C, and ^{31}P NMR spectroscopy and elemental analysis.

EXPERIMENTAL

^{1}H NMR spectra were recorded on a Bruker-250 spectrometer (at 250 MHz); ^{13}C NMR spectra were recorded on a Bruker AC-200 spectrometer (at 50.32 MHz); ^{31}P NMR spectra were recorded on a Bruker WP-80SY instrument (at 32.4 MHz, 85% H_3PO_4 as external standard). Column chromatography was carried out with silica gel L 100/160 μm. Thin layer chromatography was carried out on Silufol UV-254 plates. The hexane–dioxane 3:1 (A), and hexane–dioxane 5:1 (B), hexane–dioxane 6:1 (C), hexane–dioxane 7:1 (D), and benzene–dioxane 7:1 (E) systems were used as solvents. The identification of compounds was achieved using iodine vapor treatment or calcination. Optical activity was measured on a DIP-360 polarimeter using chloroform and dichloromethane as solvents. All syntheses were performed in dry solvents under dry oxygen-free argon.

Bis-[1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose-3-*O*-yl]cyclohexylthionophosphate (6)

A solution of 0.39 g (0.0019 mol) of cyclohexylphosphorous acid dichloride in 3 mL of dioxane was slowly dropped to a solution of 1.00 g (0.0038 mol) of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose and 0.38 g (0.0048 mol) of pyridine in 3 mL of dioxane under cooling in the dry argon atmosphere, and the mixture was stirred for 30 min. Then, the reaction mixture was filtered from the precipitated pyridinium chloride under an argon atmosphere. Sulfur (0.09 g, 0.0029 mol) and 2–3 drops of dry triethylamine were added to the filtrate, and the mixture was left to stand overnight. The excess sulfur was filtered; the filtrate was evaporated, and the residue was fractionated on a silica gel column with solvent system B as an eluent. A light-orange oily product was obtained with a yield of 1.16 g (90%); R_f 0.40 (B), $[\alpha]_D^{20}$ -35°C (c = 5, $CHCl_3$). ^{13}C NMR ($CDCl_3$): δ, ppm 23.8 (s, C(3′)); 27.0 (s, C(4′)); 25.9–27.5 (s, C($\underline{C}H_3)_2$); 33.4 (s, C(2′)); 67.6 (s, C(6)); 72.6 (s, C(5)); 77.9 (s, C(1′)); 78.7, 78.8 (s, C(3)); 80.5, 80.9 (s, C(4)); 83.8, 84.0 (s, C(2)); 105.3, 105.4 (s, C(1)); 104.5, 112.4 (s, $\underline{C}(CH_3)_2$). ^{31}P NMR ($CHCl_3$): δ, ppm 65.7 s. Analyses calculated for $C_{30}H_{49}O_{13}PS$: C, 52.93; P, 4.53; M_r, 680.76. Found: C, 53.07; P, 4.49; M_r, 639.85.

3-*O*-Phenylphosphonite-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (7a,b)

A solution of 1.06 g (0.0041 mol, 1 eq.) of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose and 0.91 g (0.0115 mol, 2.5 eq.) of pyridine in 5 mL of dioxane was slowly dropped to a solution of 0.80 g (0.0045 mol, 1.1 eq.) of dichloro(phenyl)phosphine in 3 mL of dioxane, and the mixture was stirred at room temperature for 30 min. Then, the reaction mixture was cooled, and a solution of 0.10 g (0.0057 mol) of water in 3 mL of dioxane was slowly added dropwise. The mixture was stirred at room temperature for 30 min. The precipitate of pyridinium chloride was filtered; the filtrate was evaporated, and the residue was fractionated on a silica gel column with solvent system E as an eluent. A colorless powder was obtained with a yield of 0.99 g (63%); m.p. 115°–117°C, R_f 0.51 (E), $[\alpha]_D^{20}$–16°C (c = 5, $CHCl_3$). **7a:** ^{13}C NMR ($CDCl_3$): δ, ppm 24.9–26.5 (s, C($\underline{C}H_3)_2$); 67.0 (s, C(6)); 72.4 (s, C(5)); 74.0 (s, C(3)); 81.1 (s, C(4)); 84.9 (s, C(2)); 104.8 (s, C(1)); 108.9, 111.3 (s, $\underline{C}(CH_3)_2$), 128.4 (s, C(3′)); 130.6 (s, C(2′)); 131.3 (s, C(4′)); 131.9 (d, C(1′), $^1J_{PC}$ = 153.0 Hz).^{31}P NMR ($CHCl_3$): δ, ppm 28.2 (d,$^1J_{PH}$ = 578.0 Hz).

7b: ^{13}C NMR ($CDCl_3$): δ, ppm 24.9–26.5 (s, C($\underline{C}H_3)_2$); 67.4 (s, C(6)); 72.4 (s, C(5)); 74.6 (s, C(3)); 83.4 (s, C(4)); 83.5 (s, C(2)); 105.0 (s, C(1)); 109.2, 112.2 (s, $\underline{C}(CH_3)_2$), 128.7 (s, C(3′)); 130.6 (s, C(2′)); 131.3 (s, C(4′)); 131.9 (d, C(1′), $^1J_{PC}$ = 153.0 Hz). ^{31}P NMR ($CHCl_3$): δ, ppm 26.5 (d,$^1J_{PH}$ = 577.3 Hz). Analyses calculated for $C_{18}H_{25}O_7P$: C, 56.25; H, 6.56; P, 8.06. Found: C, 56.15; H, 6.66; P, 7.98.

3-*O*-Ethylphosphite-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (8)

A solution of 1.06 g (0.0041 mol, 1 eq.) of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose and 0.81 g (0.0103 mol, 2.5 eq.) of pyridine in 5 mL of dioxane was slowly dropped to a solution of 0.66 g (0.0045 mol, 1.1 eq.) of ethylphosphorous acid dichloride in 3 mL of dioxane, and the mixture was stirred at room temperature for 30 min. Then, the reaction mixture was cooled, and a solution of 0.08 g (0.0045 mol) of water in 3 mL of dioxane was slowly added dropwise. The mixture was stirred at room temperature for 30 min. The precipitate of pyridinium chloride was filtered; the filtrate was evaporated, and the residue was fractionated on a silica gel column with solvent system B as an eluent. A colorless powder was obtained with a yield of 1.04 g (72%), R_f 0.20 (B), $[\alpha]_D^{20}$ −15°C (c = 5, $CHCl_3$). ^{13}C NMR ($CDCl_3$): δ, ppm 15.4, 15.5 (s, $OCH_2\underline{C}H_3$); 24.4–26.2 (s, C($\underline{C}H_3)_2$); 61.2, 61.4 (d, $O\underline{C}H_2CH_3$, $^2J_{PC}$ = 6.5 Hz,

$^{2}J_{PC} = 7.6$ Hz); 66.3, 66.6 (s, C(6)); 71.3, 71.6 (s, C(5)); 77.6, 77.6 (s, C(3)); 79.6, 79.7 (s, C(4)); 83.0, 83.2 (s, C(2)); 104.4, 104.6 (s, C(1)); 108.0, 110.6 and 108.6, 111.5 (s, $\underline{C}(CH_3)_2$). ^{31}P NMR ($CHCl_3$): δ, ppm 7.4 (d,$^{1}J_{PH} = 715.8$ Hz), 8.3 (d,$^{1}J_{PH} = 715.8$ Hz). Analyses calculated for $C_{14}H_{25}O_8P$: C, 47.73; P, 8.79. Found: C, 47.49; P, 8.61.

Synthesis of 3-*O*-Ethylphosphite-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (8) Using Ethylphosphorous Acid Tetraethyldiamide

Ethylphosphorous acid tetraethyldiamide (0.88 g, 0.0050 mol) was added to a solution of 0.94 g (0.0036 mol) of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose in 5 mL of benzene, and the mixture was refluxed under dry argon for 12 h. Absolute acetic acid (0.19 g, 0.0032 mol) in 3 mL of benzene was then dropped to the solution under cooling. The reaction mixture was stirred for 2 h and left to stay overnight. The solvent was evaporated, and the mixture was eluted from the silica gel column with solvent system B. Yield was 0.76 g (60%).

3-*O*-Butylphosphite-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (9)

A solution of 1.01 g (0.0039 mol, 1 eq.) of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose and 0.77 g (0.0098 mol, 2.5 eq.) of pyridine in 5 mL of dioxane was slowly dropped to a solution of 0.75 g (0.0045 mol, 1.1 eq.) of butylphosphorous acid dichloride in 3 mL of dioxane under dry argon, and the mixture was stirred at room temperature for 30 min. Then, the reaction mixture was cooled, and a solution of 0.08 g (0.0045 mol) of water in 3 mL of dioxane was slowly added dropwise. The mixture was stirred at room temperature for 30 min. The precipitate of pyridinium chloride was filtered; the filtrate was evaporated, and the residue was fractionated on a silica gel column with solvent system C as an eluent. A colorless oily product was obtained with a yield of 1.19 g (80%); R_f 0.16 (C), $[\alpha]_D^{20}$ -14.5°C (c = 5, $CHCl_3$). ^{13}C NMR ($CDCl_3$): δ, ppm 12.6 (s, $OCH_2CH_2CH_2\underline{CH_3}$); 17.7 (s, $OCH_2CH_2\underline{CH_2}CH_3$); 24.2–25.9 (s, $C(\underline{C}H_3)_2$); 31.4 (s, $OCH_2\underline{CH_2}CH_2CH_3$); 64.7 (d, $O\underline{CH_2}CH_2CH_2CH_3$, $^{2}J_{PC} = 7.5$ Hz); 66.3, 66.4 (s, C(6)); 71.2, 71.5 (s, C(3)); 77.2 (s, C(5)); 79.5, 79.6 (s, C(4)); 82.8, 83.0 (s, C(2)); 104.3 (s, C(1)); 108.3, 111.2 s ($\underline{C}(CH_3)_2$). ^{31}P NMR (C_6H_6): δ, ppm 8.1 (d,$^{1}J_{PH} = 717.6$ Hz); 7.2 (d,$^{1}J_{PH} = 728.8$ Hz). Analyses calculated for $C_{16}H_{29}O_8P$: C, 50.52; P, 8.14. Found: C, 50.43; P, 8.10.

3-*O*-Cyclohexylphosphite-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (10)

A solution of 1.02 g (0.0039 mol, 1 eq.) of 1,2:,6-di-*O*-isopropylidene-α-D-glucofuranose and 0.77 g (0.0098 mol, 2.5 eq.) of pyridine in 5 mL of dioxane was slowly dropped to a solution of 0.86 g (0.0043 mol, 1.1 eq.) of cyclohexylphosphorous acid dichloride in 3 mL of dioxane under cooling, and the mixture was stirred at room temperature for 30 min. Then, the reaction mixture was cooled again, and a solution of 0.08 g (0.0045 mol) of water in 3 mL of dioxane was slowly added dropwise. The mixture was stirred at room temperature for 30 min. The precipitate of pyridinium chloride was filtered; the filtrate was evaporated, and the residue was fractionated on a silica gel column with solvent system B as an eluent. A yellowish oily product was obtained with a yield of 1.03 g (65%); R_f 0.40 (B), $[\alpha]_D^{20}$–15.5°C (c = 5, $CHCl_3$). ^{13}C NMR ($CDCl_3$): δ, ppm 22.8, 23.5 (s, C(3′)); 25.3–25.4 (s, C($\underline{CH_3}$)$_2$); 26.5, 27.0 (s, C(4′)); 31.7, 33.7 (s, C(2′)); 67.4 (s, C(6)); 72.2, 72.5 (s, C(5)); 75.4 (d, C(3)), $^2J_{PC}$ = 4.5 Hz); 77.9 (d, C(1′)), $^2J_{PC}$ = 4.3 Hz); 80.6, 80.7 (s, C(4)); 83.9, 84.1 (s, C(2)); 105.2, 105.3 (s, C(1)); 109.1, 111.9 and 109.2, 112.0 (s, $\underline{C}(CH_3)_2$). ^{31}P NMR (CH_2Cl_2): δ, ppm 6.7 (d,$^1J_{PH}$ = 705.1 Hz); 5.5 (d,$^1J_{PH}$ = 708.7 Hz). Analyses calculated for $C_{18}H_{31}O_8P$: C, 53.20; P, 7.62. Found: C, 53.02; P, 7.52.

3-*O*-[(Diethylaminomethylene)-*O*-butylphosphonate]-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (12)

A solution of 0.84 g (0.0057 mol) of bis(diethylamino)methane in 2 mL of chloroform was dropped to a solution of 1.45 g (0.0038 mol) of 3-*O*-butylphosphosphite-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose in 3 mL of chloroform, and the reaction mixture was stirred for 10 h. Then, the solvent was evaporated, and the mixture was separated on a silica gel column using solvent mixture D as an eluent. A yellow fluid oily product with a characteristic odor was obtained with a yield of 1.13 g (64%); R_f 0.32 (D), $[\alpha]_D^{20}$ −18°C (c = 5, $CHCl_3$). ^{13}C NMR ($CDCl_3$): δ, ppm 10.4, 10.5 (s, $NCH_2\underline{CH_3}$); 12.5 (s, $OCH_2CH_2CH_2\underline{CH_3}$); 17.6 (s, $OCH_2CH_2\underline{CH_2}CH_3$); 24.2–25.7 (s, C($\underline{C}H_3)_2$); 31.4, 31.5 (s, $OCH_2\underline{CH_2}CH_2CH_3$); 47.1, 47.6 (d, P-$CH_2$, $^1J_{PC}$ = 160.6 Hz, $^1J_{PC}$ = 168.4 Hz); 47.1, 47.2 (d, $N\underline{CH_2}CH_3$, $^3J_{PC}$ = 7.3 Hz, $^3J_{PC}$ = 7.7 Hz); 64.5, 64.6 (d, $O\underline{CH_2}CH_2CH_2CH_3$, $^2J_{PC}$ = 8.1 Hz, $^2J_{PC}$ = 8.2 Hz); 66.0, 66.2 (s, C(6)); 71.2, 71.2 (s, C(3)); 77.0, 77.2 (s, C(5)); 79.5 (s, C(4)); 82.9, 83.1 (s, C(2)); 104.0 (s, C(1)); 108.0, 110.7 and 108.7, 110.9 (s, $\underline{C}(CH_3)_2$). ^{31}P NMR ($CHCl_3$): δ, ppm 26.4 s. Analyses calculated for $C_{21}H_{40}NO_8P$: C,

54.18; H, 8.66; N, 3.01; P; 6.65. Found: C, 54.14; H, 8.52; N, 2.99; P, 6.49.

3-*O*-[(Diethylaminomethylene)-*O*-cyclohexylphosphonate]-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (13)

A solution of 0.87 g (0.0059 mol) of bis(diethylamino)methane in 2 mL of chloroform was dropped to a solution of 1.59 g (0.0039 mol) of 3-*O*-cyclohexylphosphosphite-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose in 3 mL of chloroform, and the reaction mixture was stirred for 10 h. Then, the solvent was evaporated, and the mixture was separated on a silica gel column using solvent mixture B as an eluent. A yellow oily fluid product with a characteristic odor was obtained with a yield of 1.28 g (67%); R_f 0.36 (B), $[\alpha]_D^{20}$ -21°C (c = 5, $CHCl_3$). ^{13}C NMR ($CDCl_3$): δ, ppm 11.1, 11.2 (s, $NCH_2\underline{C}H_3$); 23.1 (s, C(3′)); 24.8–26.4 (s, $C(\underline{C}H_3)_2$); 26.5, 26.7 (s, C(4′)); 33.2, 33.3 (d, C(3′)), $^3J_{PC}$ = 4.2 Hz, $^3J_{PC}$ = 4.8 Hz); 47.7, 47.8 (d, $N\underline{C}H_2CH_3$, $^3J_{PC}$ = 8.4 Hz, $^3J_{PC}$ = 9.3 Hz); 48.8, 49.5 (d, P–CH_2, $^1J_{PC}$ = 161.5 Hz, $^1J_{PC}$ = 170.2 Hz); 66.6, 66.8 (s, C(6)); 71.9, 72.0 (s, C(5)); 75.1, 75.2 (d, C(3), $^2J_{PC}$ = 18.4 Hz, $^2J_{PC}$ = 18.9 Hz); 77.8, 78.1 (s, C(1′)), 80.1, 80.2 (s, C(4)); 83.6, 83.8 (s, C(2)); 104.6 (s, C(1)); 108.7, 111.4 and 108.7, 111.7 (s, $\underline{C}(CH_3)_2$). ^{31}P NMR ($CHCl_3$): δ, ppm 25.4 s. Analyses calculated for $C_{23}H_{42}NO_8P$: C, 56.20; H, 8.61; N, 2.85; P, 6.30. Found: C, 56.25; H, 8.49; N, 2.72; P, 6.25.

3-*O*-[(1′-Hydroxy-2′,2′,2′-trichloroethyl)-*O*-butylphosphonate]-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (14)

A solution of 1.18 g (0.0080 mol) of freshly distilled chloral in 2 mL of chloroform was dropped to a solution of 1.22 g (0.0032 mol) of *O*-butylphosphite-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose in 3 mL of chloroform. The mixture was stirred and heated in a glycerin bath to 45–47°C for 5 h. Then, the solvent was evaporated, and the mixture was separated on a silica gel column using solvent system A as an eluent. A colorless oily product was obtained with a yield of 0.66 g (39%); R_f 0.36 (A), $[\alpha]_D^{20}$ -6°C (c = 5, $CHCl_3$). ^{13}C NMR ($CDCl_3$): δ, ppm 13.4 ($OCH_2CH_2CH_2\underline{C}H_3$); 18.5 ($OCH_2CH_2\underline{C}H_2CH_3$); 24.7–26.6 ($C(\underline{C}H_3)_2$); 32.0–32.2 ($OCH_2\underline{C}H_2CH_2CH_3$); 66.8–67.2 ($O\underline{C}H_2CH_2CH_2CH_3$); 67.5–68.0 (C(6)); 71.8–72.5 (C(3)); 77.2 (C(5)); 78.7–79.0 (C(2)); 80.3–80.5 (C(4)); 81.1–83.0 (CHOH); 83.7–84.4 (CCl_3); 104.9–105.0 (C(1)); 109.9–112.4 ($\underline{C}(CH_3)_2$). ^{31}P NMR ($CHCl_3$): δ, ppm 14.9 s. Analyses calculated for $C_{18}H_{30}Cl_3O_9P$: C, 40.96; H, 5.73; P, 5.27. Found: C, 41.09; H, 5.59; P, 5.30.

3-*O*-[(1′-Hydroxy-2′,2′,2′-trichloroethyl)-*O*-cyclohexylphosphonate]-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (15)

A solution of 1.40 g (0.0095 mol) of freshly distilled chloral in 2 mL of chloroform was dropped to a solution of 1.54 g (0.0032 mol) of *O*-cyclohexylphosphite-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose in 3 mL of chloroform. The mixture was stirred and heated in a glycerin bath to 45–47°C for 7 h. Then, the solvent was evaporated, and the mixture was separated on a silica gel column using solvent system A as an eluent. A colorless oily product was obtained with a yield of 0.48 g (27%); R_f 0.41 (A), $[\alpha]_D^{20}$ −8°C (c = 5, $CHCl_3$). ^{13}C NMR ($CDCl_3$): δ, ppm 22.7–23.7 (C(3′)); 24.6–25.9 (C($\underline{C}H_3$)$_2$); 26.4 (C(4′)); 30.5–34.7 (C(2′)); 66.5–67.1 (C(6)); 71.8–73.9 (C(5)); 77.2 (C(1′)); 78.1 (C(3)); 80.0–80.1 (C(4)); 80.9–81.6 (CHOH); 83.2–84.8 (C(2)); 97.04–98.6 (CCl_3); 104.6 (C(1)); 108.7–109.6, 111.1–112.1 ($\underline{C}(CH_3)_2$). ^{31}P NMR ($CHCl_3$): δ, ppm 14.1 s. Analyses calculated for $C_{20}H_{32}Cl_3O_9P$: C, 43.38; H, 5.82; P, 5.59. Found: C, 43.45; H, 5.70; P, 5.41.

CONCLUSION

The results obtained allow us to conclude that monosaccharide hydrophosphoryl derivatives can be synthesized with good yields and used in reactions with electrophilic agents. This shows promise for the design of complex carbohydrate–phosphoric structures, which are candidate bioregulators and ligands for metal complex catalysts.

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