

A common route to the synthesis of 1,3,4-oxadiazole -2-thione and 1,2,4-triazole -3-thiols derivatives of trioses and pentoses as models for acyclic C-nucleosides

Mohamed Belkadi * and Adil A. Othman

* *Department of Industrial Chemistry, Faculty of Science, University of Sciences and Technology in Oran, (U.S.T.Oran), P.O.Box 1505 El-M'naouer, Oran 31000, Algeria*
E-mail: medbelkadiz2@yahoo.fr

Abstract

The 5-(1,2-dihydroxy-ethyl)-3*H*-[1,3,4]oxadiazole-2-thione (**12**) and 1-(5-mercapto-4*H*-[1,2,4]triazole-3-yl)-ethane-1,2-diol (**13**) derived from (±) glyceraldehyde (resembles trioses) have been synthesized from glycerol (**1**) via a common route. The synthesis of the optical active 5-(2,2-dimethyl-[1,3]dioxolan-4-yl)-3*H*-[1,3,4] oxadiazole-2-thione (**17**) and 5-(2,2-dimethyl-[1,3]dioxolan-4-yl)-4*H*-[1,2,4]triazole-3-thiol (**18**) may be achieved by the same common route when the D- glyceraldehyde (**3**) was obtained by cleavage oxidation of 1,2:5,6-Di-*O*-isopropylidene D-mannitol (**15**). Similar derivatives **23** and **24** of D-xylose (**19**) (resembles pentoses) may also be synthesized by the same common route from (tetrahydro-[1,3]dioxino[5,4-d][1,3]dioxin-4-yl)-methanol (**21**). This common route provides a simple synthetic pathway to acyclic C-nucleosides and to less extent to cyclic C-nucleosides.

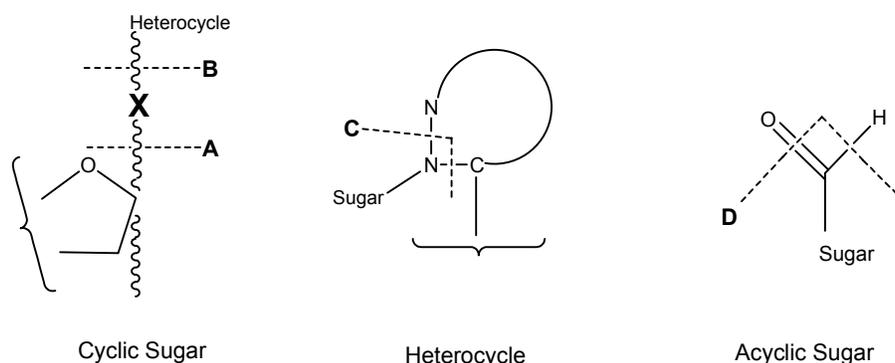
Keywords:(±)Glyceraldehydes,1,2:5,6-Di-*O*-isopropylidene-D-mannitol,5-(1,2-dihydroxy ethyl)-3*H*-[1,3,4]oxadiazole-2-thione,1-(5-mercapto-4*H*-[1,2,4]triazole-3-yl)-ethane-1,2-diol, C-nucleosides

Introduction

Hydrazides and related compounds have been described as useful building blocks for the assembly of various heterocyclic rings. Thus, different carbohydrazides were found to be useful as medicines. The synthesis of compounds incorporating both 1,2,4-triazole, and 1,3,4-oxadiazole rings has been attracting widespread attention due to their diverse pharmacological proprieties such as antimicrobial, anti-inflammatory, analgesic and antitumor activities.

Many commonly known cyclic N-nucleosides as well as acyclic analogues have strong biological effects.^{1, 2, 3} The less common O-, S- and C-nucleosides are also known to have antiproliferating activity and can be used for antiviral, anti-cancer and anti-aids therapies.⁴

The synthesis of the different kinds of the nucleosides can be performed in any one of the four strategies (A, B, C and D).⁵



Strategy (A) involves a substitution of the glycosidic link X with a leaving group (e.g. halogen, acetate, etc...) to replace it with the base acting as the nucleophile to build up the desired heterocycles.

Strategy (B) achieving the nucleosides from hetero-sugars (X = S) as in thio-sugars where S acts as nucleophile to react with heterocyclic ring.

Strategy (C) use a sugar containing a base (X = N) as in amino-sugars where N acts as a nucleophile to build up the heterocycles.

Strategy (D) involves nucleophilic addition reaction to the aldehydic carbonyl followed with the lost of water followed by building up the heterocycles.

C-nucleosides are excellent natural products antibiotics and in comparison with the normal nucleosides, they contain no acetal unit and hence they are much more stable compared to normal nucleosides and nucleotides.

The synthetic route to the cyclic C-nucleosides using sugar lactones, while for the acyclic analogue, more often followed strategy (D).

The 1,3,4-oxadiazole derivatives show leprostatic and tuberculostatic properties and exhibit antibacterial, antiproteolytic and anticonvulsant activities. Also they have analgesic, antipyretic, antiphlogistic, bactericides, insecticides, fungicidal and several other biological activities.⁶

The relatively simple 1,2,4-triazoles display biological activities such as inhibition of cholinesterase, interference with mitosis and reversible denaturation of serum proteins. The 1,2,4-triazole thiones afford some protection of mice against irradiation with X-rays, and have anti-inflammatory properties. They have appreciable biochemical effects when replacing histidine derivatives in nucleic acids. Also, compounds with a thiourea function NH-(CS)-NH have a strong potential for manufacturing drugs since the SH group can easily converted to their S-substituted derivatives.⁷ As a continuation of our investigation of antimicrobial activities of 1,3,4-oxadiazole-thione and 1,2,4-triazole-thiole derivatives, we wish to report a common route to the synthesis of 1,3,4-oxadiazolo-thiones **12**, **17**, **23**, and 1,2,4-triazolo-thiols **13**, **18**, **24** as model compounds for acyclic C-nucleosides.

Results and Discussion

Scheme 1 shows the common route for the synthesis of open chain C-nucleosides possessing a 1,3,4-oxadiazolo-2-thione **12** and a 1,2,4-triazolo-3-thiol **13** derived from glycerol. This route initially required a selective protection of the adjacent OH groups of glycerol in order to leave the terminal OH group for further modifications.

Racemic 2,3-*O*-isopropylidene glycerol (**2**) has been prepared in a excellent yield (98%) by refluxing glycerol with an excess of acetone and a catalytic amount of acid when a Dean-Stark apparatus was used to remove the water which formed during the reaction. The amount of acetone may be reduced if chloroform was utilized as a reaction medium. Between the two acids used (concentrated H₂SO₄ or *p*-toluensulfonic acid), the latter was found to be more effective and to give a higher yield.

The (±)-2,3-*O*-isopropylidene glyceric acid (**4**) was prepared by two routes. In the first route, the direct oxidation of (±)-2,3-*O*-isopropylidene glycerol (**2**) with KMnO₄ / KOH gave the potassium salt **6** in 81 % yield, in addition to the starting alcohols.

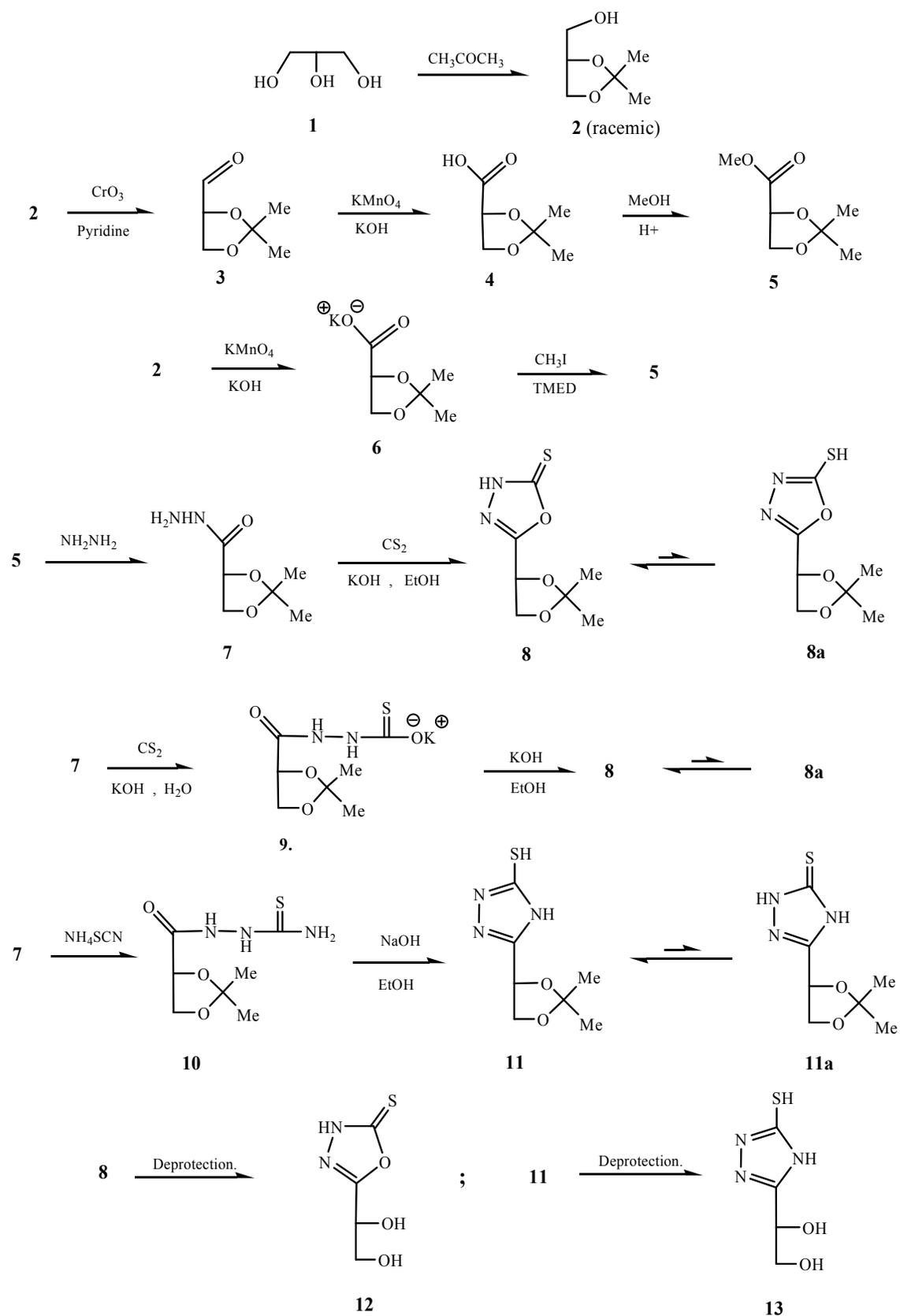
The second route was achieved by a complete oxidation of the **2** with CrO₃ / pyridine to give the corresponding aldehyde **3**. The crude aldehyde **3** was oxidized with KMnO₄ / KOH then acidified with a mineral acid (HCl) to give a quantitative yield of the corresponding acid **4**.

The (±)-methyl-2,3-*O*-isopropylidene glycerate (**5**) was obtained either by direct esterification of **4** with methanol in presence of conc. H₂SO₄ or by treatment of the potassium salt **6** with methyl iodide in presence of N,N,N',N'-tetramethylethylenediamine (TMED).

In case the methylation was performed on crude **6**, 1-methoxy-2,3-*O*-isopropylidene glycerol as a side product was isolated. The second route gave a better yield since the latter procedure does not involve the risk of a back hydrolysis of the ester group and the protecting isopropylidene ring.

The racemic hydrazide **7** was prepared in a yield of about 90 % by treating the ester **5** with hydrazine monohydrate (55 %). The product was identified by IR which showed a moderately strong band at 3258 cm⁻¹ region for the free and bonded N-H and a band at 1631 cm⁻¹ for CO-N. The structure **7** was confirmed by ¹H-NMR which exhibited a signal at 8 ppm for N-H and mass spectrometry which showed the fragment M+1 = 161.081 for C₆H₁₂N₂O₃.

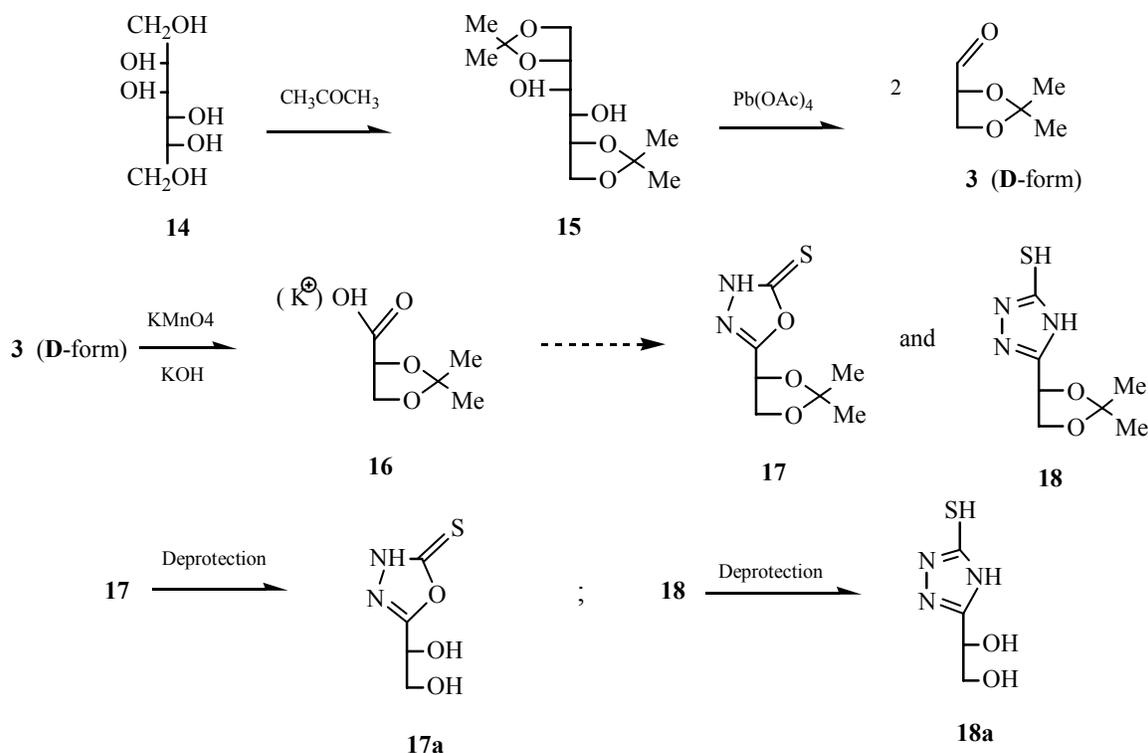
When the hydrazide **7** was refluxed with CS₂ in absolute ethanol and KOH (0.3 moles) revealed into (±)-5-(2,2-dimethyl-[1,3]dioxolan-4-yl)-3*H*-[1,3,4]oxadiazole-2-thione (**8**). The characteristic bands in IR of this compound showed at regions 1280 cm⁻¹ (C=S) and 1675 cm⁻¹ (C=N). The position of the C=N band suggested that the oxadiazole existed as the thione tautomer **8** rather than the ene-thiol form **8a** which normally exhibited a band at a lower region (in about 1638 cm⁻¹) due to maximum conjugation.⁸ Further support for the thione form came from ¹H-NMR which exhibited only one proton as a singlet at lower field 7.01 ppm for N-H and no signal around 13 to 14 ppm where the S-H is normally shown.⁹ The product **8** also shown a fragment [M+H] = 203.04 in mass spectrometry.



Scheme 1. Common pathway to the synthesis of compounds **12** and **13**

The potassium (\pm)-2,2-dimethyl-[1,3]dioxolan-4-carboxylic-acid-hydrazide-thio-semi-carbazinate **9** was obtained in a yield 95 % by treatment of the hydrazide **7** with CS₂ in aqueous KOH under reflux for five hours.¹⁰ The IR spectrum of the product exhibited characteristic bands at 3258 cm⁻¹ (OCNH), 1580 cm⁻¹ (NH), and 1238 cm⁻¹ (C=S). The mass spectrum showed the major fragment [M+1] = 259.01 for C₇H₁₁N₂O₄SK. When **9** was heated with ethanolic KOH it gave rise to **8**.

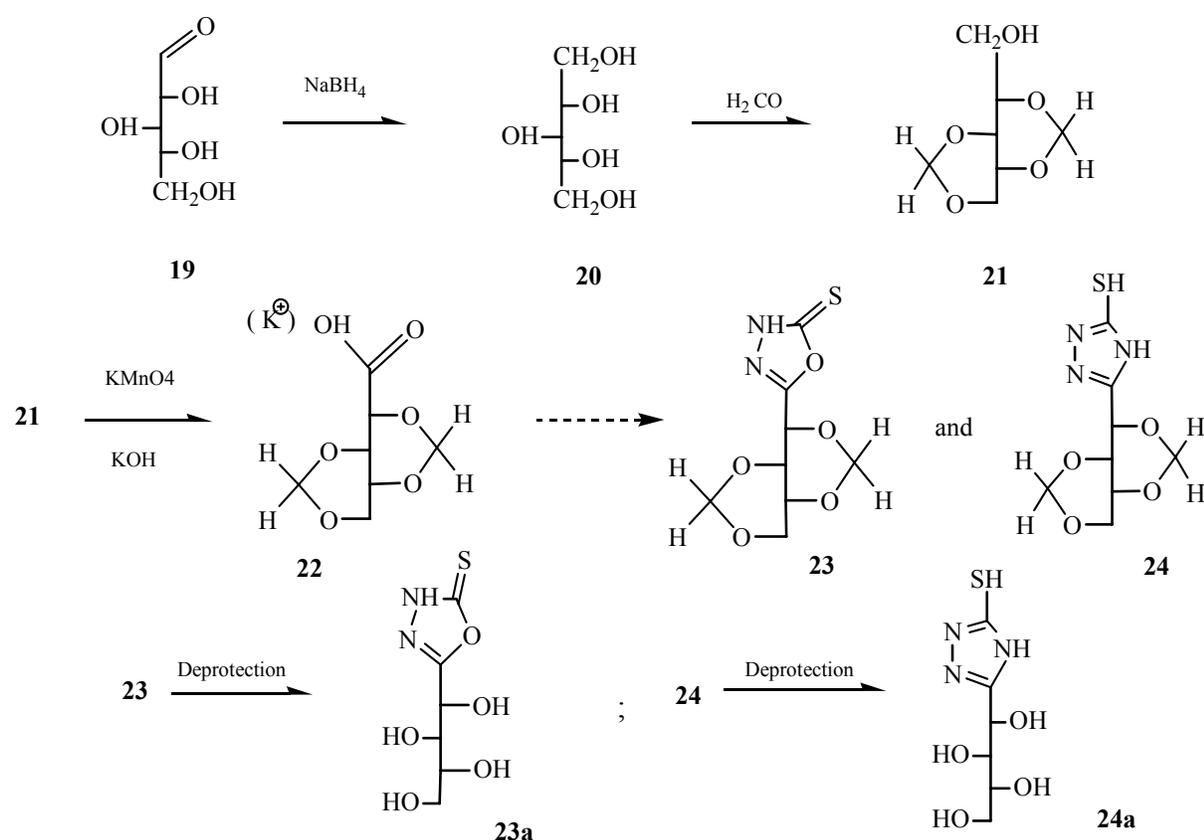
The synthesis of the (\pm)-5-(2,2-dimethyl-[1,3]dioxolan-4-yl)-4*H*-[1,2,4]triazole-3-thiol (**11**) was achieved in two steps from hydrazide **7**. The first step was the preparation of (\pm)-2,2-dimethyl-[1,3]dioxolan-4-carboxylic-acid-hydrazide-thioformamido-semi-carbazide (**10**) by treating the hydrazide **7** with ammonium thiocyanate in dry benzene under reflux for six hours. The resulting product after isolation showed an IR spectrum which exhibited a broad band centered at 3100 cm⁻¹ region for free and bonded N-H; another band at 1665 cm⁻¹ (C=O) and at 1280 cm⁻¹ (C=S). Mass spectrum showed a fragment [M+H] = 220.07. The second step involved the treatment of **10** with NaOH in absolute ethanol under reflux for five hours to give **11**. IR spectrum exhibited the following characteristic bands 3200 cm⁻¹ (NH), 2860-2760 cm⁻¹ (SH), and 1670 cm⁻¹ (C=N). ¹H-NMR showed a singlet at 3.01 ppm for S-H. Mass spectrum exhibited a fragment [M+H] = 202.057 attributed for C₇H₁₁N₃O₂S. These informations suggested that the triazole **11** found mostly in the thiol form. The synthesis of the optical active oxadiazole **17** and triazole **18** derivatives of D-glyceraldehyde can be achieved according to Scheme 2.



Scheme 2. Common route preparation of D-1,2-O-isopropylidene 1,3,4-oxadiazole (**17**) and 1,2,4-triazole (**18**) thioles from D-mannitol.

The acetonation of D-mannitol (**14**) gave 1, 2:5, 6-Di-*O*-isopropylidene-D-mannitol (**15**).¹¹ The oxidation of **15** with lead tetra acetate led to 2,3-*O*-isopropylidene-D-glyceraldehyde (**3a**) which on oxidation with $\text{KMnO}_4 / \text{KOH}$ followed by acidification with mineral acid to give 2,3-*O*-isopropylidene-D-glyceric acid (**16**) which can be used as starting material for preparation of **17** and **18** by following the same steps described in Scheme 1.

For the synthesis of 1, 3, 4-oxadiazole **23** and 1, 2, 4-triazole **24** derived from pentose, e.g. D-xylose (**19**), Scheme 3 was followed. The reduction of D-xylose (**19**) with NaBH_4 afforded D-xylitol (**20**)¹² which on reaction with formaldehyde gave (tetrahydro-[1,3]dioxino[5,4-d][1,3]dioxin-4-yl)-methanol (**21**) which on oxidation with KMnO_4 gave the corresponding acid **22**, which can be used as starting material for the synthesis of **23** and **24** by following reaction sequence described in Scheme 1.



Scheme 3. Common route to the synthesis 1,3,4-oxadiazole (**23**) and 1,2,4-triazole (**24**) thioles from D-xylose.

Experimental Section

General Procedures. Chemicals were purchased from Fluka and Aldrich. Melting points were determined with a Buchi Apparatus and are uncorrected. The progress of reactions were followed by thin layer chromatography (TLC) prepared in our laboratory using Silica Gel (Merck) on glass (layer thickness 0.25 mm) used without pretreatment. Eluents used volume-to-volume (v/v), and the spots were detected by exposure to iodine vapor for a few minutes. All solvents evaporations were performed in a Buchi rotary evaporator under diminished pressure. The IR spectra were measured as potassium bromide pellets using Perkin-Elmer 1600 FTIR spectrometer. The ^1H NMR spectra were obtained using a Bruker AC 250 NMR and were recorded at 250 MHz. Chemical shifts are reported in part per million δ (ppm) using internal TMS and DMSO- d_6 as solvent. The mass spectra were measured on DX 300-SX102 spectrometer using a FAB (fast atom bombardment) as ionization mode.

(±)-2,2-Dimethyl-[1,3]dioxolan-4-yl-methanol (2).¹³ Glycerol (**1**) (15.0 g, 0.16 mol), acetone (400 mL) in petroleum ether b.p. 60-80°C (400 mL) and TsOH (1.0 g) were mixed and heated under reflux for 6 h in which the water formed during the reaction was removed continuously by a Dean-Stark apparatus. The reaction mixture was cooled to room temperature and Na_2CO_3 (1.3 g) was added gradually. The mixture was stirred for 30 min, filtered, and the filtrate was evaporated to dryness to give the crude product. The crude product was vacuum distilled (10 mm Hg) to give the pure (±)-2,3-O-isopropylidene glycerol (**2**) as a colorless syrup (16.49 g, 76.6%), b.p. 193°C, $\alpha_D^{20} = 1.4378$.¹¹

(±)-2,2-Dimethyl-[1,3]dioxolan-4-carbaldehyde (3). The racemic mixture **2** (5.0 g, 37 mmol) in CH_2Cl_2 (2 mL), added to it freshly prepared CrO_3 / pyridine /HCl (9.7 g, 0.1 mol) suspended in CH_2Cl_2 (60mL). The mixture was kept into an ice bath 0-4°C for 1.5 h with an aid of magnetic stirring (TLC (benzene/chloroform, 3:7 Rf: 0.52 showed the total consumption of glycerol derivative **2**). The CH_2Cl_2 was evaporated down under vacuum at room temperature, the residue dissolved in dry Et_2O and the filtrate and the residue were washed further with ether (1 mL) The combined filtrate and washing were evaporated to dryness under vacuum at room temperature to give a greenish syrup (3.79 g, 75.8 %). mp: 105-110 °C; IR exhibited bands at 2780 cm^{-1} (CH) and 1725 cm^{-1} ($>\text{C}=\text{O}$). ^1H NMR (250 MHz, TMS) δ (ppm) 1.40 (m, 6H, 2 CH_3), 4.19(d, 2H, OC- CH_2), 4.76 (s, 1H, OC-CH), 9.72 (s, 1H, CHO); MS m/z : 131.066 (M^++1), 114.06 (12.97 %); HRMS Calcd for $\text{C}_6\text{H}_{10}\text{O}_3$: 130.061; Found: 131.070.

(±)-2,2-Dimethyl-[1,3]dioxolan-4-carboxylic acid (4). The aldehyde **3** (0.2 g; 1.53 mmol) in acetone (3 mL) was treated with a solution of KMnO_4 (1.25 mg in 7 mL H_2O) dropwise at 0°C with the aid of magnetic stirring. The mixture was stirred for 1 h at 20-25°C, the period shown by TLC to complete conversion of the aldehydes to acid [TLC (benzene/ chloroform, 3:7), Rf: 0.17]. A small amount of activated charcoal was added and the reaction mixture was warmed on a water bath at 50°C for 10 minutes. The reaction mixture was then filtered and just acidified with few drops of HCl and extracted with petroleum ether 60-80, and evaporated to dryness to give a white solid, which was recrystallized from light petroleum ether to give colorless needles

(0.15 g, 68%), mp. 68°C ; IR exhibited bands at 2500 cm⁻¹ (OH) and 1710 cm⁻¹ (>C=O). ¹H NMR (250 MHz, TMS) δ (ppm) 1.41 (m, 6H, 2CH₃), 4.13(d, 2H, OC-CH₂), 4.76 (s, 1H, OC-CH), 11.0 (s, 1H, COOH); MS *m/z*: 147.051 (M⁺+1), 129.061 (12.55 %), 114.07 (22.67 %), 101.063 (31.49 %); HRMS Calcd for C₆H₁₀O₄: 146.058; Found: 146.141.

Potassium (±)-2,2-dimethyl-[1,3]dioxolan-4-carboxylate (6) . The racemic mixture **2** (0.4 g, 3.0 mmol) in H₂O (40 mL) was added to an aqueous solution (containing KOH, 180 mg in 40 mL H₂O). A solution of aqueous KMnO₄ (50%) was added dropwise at 0-10 ° C with the aid of stirring until the color of permanganate ion was retained for 30 min. The excess of permanganate was decomposed by addition of MeOH dropwise. Solvents were evaporated to dryness and the residue was suspended in absolute ethanol (100 mL) for two times and again evaporated down to dryness to crude salt (0.48 g) which was used without further purification.

2,2-Dimethyl-[1,3]dioxolan-4-carboxylic acid methyl ester (5)

Method A. From (±)-2,2-dimethyl-[1,3]dioxolan-4-carboxylic acid (4). The acid **4** (1.0 g), methanol (5 mL), toluene (10 mL) and H₂SO₄ (6 drops) were heated under reflux in an oil bath (105-110 °C) for 4 h. TLC (CHCl₃/MeOH, 6:4), Rf: 0.89. The reaction mixture was cooled to room temperature, neutralized with saturated aqueous Na₂CO₃ solution with the aid of magnetic stirring. Two layers separated, the organic layer was washed with water and dried over MgSO₄, filtered and evaporated to dryness to give the ester **5** as colourless syrup (480 mg, 89.5%). IR showed a band at 1740 cm⁻¹ characteristic of ester CO, and 2845 cm⁻¹ for methoxy group (O-CH₃). ¹H NMR (250 MHz, TMS) δ (ppm) 1.40 (m, 6H, 2CH₃), 3.67(m, 3H, O-CH₃), 4.25 (d, 2H, OC-CH₂), 4.73 (s, 1H, OC-CH); MS *m/z*: 161.074 (M⁺+1), 145.055 (9.95%), 129.057 (19.88 %), 114.06 (29.19 %); HRMS Calcd for C₇H₁₂O₄: 160.074; Found: 161.168.

Method B. From potassium,(±)-2,2-dimethyl-[1,3]dioxolan-4-carboxylate (6). A suspension of potassium-(±)-2,2-dimethyl-[1,3]dioxolan-4-carboxylate (**6**) (300 mg) in MeCN (10 mL) and methyl iodide (1.7 g, 0.60 mol) in the presence of N,N,N',N'-tetramethylethylenediamine (TMED, 100 mg, 0.04 mol) was stirred vigorously at 50°C for 5 h (TLC CHCl₃ / MeOH, 6:4), Rf: 0.90). The reaction mixture was cooled to room temperature and filtered. The residue was washed with a few drops of MeCN. The combined filtrate and washing was evaporated to dryness under reduced pressure to give a light syrup of crude ester **5** (249 mg). Chromatography with a silica gel column (30 cm long) gave the side product methoxy-2,3-*O*-isopropylidene glycerol as colorless syrup, bp 72 °C. The pure ester **5** as colorless syrup (198 mg, 83%, bp 88°C) was recovered. IR showed a band at 1740 cm⁻¹ characteristic of ester CO, and 2845 cm⁻¹ for methoxy group (O-CH₃). ¹H NMR (250 MHz, TMS) δ (ppm) 1.41 (m, 6H, 2CH₃), 3.67(m, 3H, O-CH₃), 4.25 (d, 2H, OC-CH₂), 4.73 (s, 1H, OC-CH); MS *m/z*: 161.074 (M⁺+1), 147.065 (8.70 %); HRMS Calcd for C₇H₁₂O₄: 160.074; Found: 161.168.

2,2-Dimethyl-[1,3]dioxolan-4-carboxylic acid hydrazide (7). The carboxylic acid methyl ester **5** (0.2 mL, 1.6 mmol) in methanol (1.1 mL) was added to hydrazine hydrate (0.32 mL, 6.4 mmol), and the solution was refluxed in a water bath for 6 h. TLC (CH₃Cl / MeOH, 6:4), showed consumption of the ester **5** and formation of the hydrazide **7** (Rf: 0.75). The solvent was removed

in *vacuo* and the residue was dissolved in EtOAc (20 mL); and washed with saturated aqueous NaCl (20 mL), then dried over anhydrous MgSO₄ and filtered. The solvent was removed in *vacuo* to afford a white crystalline solid **8** (0.679 g, 89 %), mp 109-113 °C; IR exhibited bands at 3258 cm⁻¹ (OC-NH) and 1580 cm⁻¹ (RNH₂). ¹H NMR (250 MHz, TMS) δ (ppm) 1.40 (m, 6H, 2CH₃), 2.00 (s, 1H, NH₂), 4.14(d, 2H, OC-CH₂), 4.84 (s, 1H, OC-CH), 8.00 (s, 1H, C-NH); MS *m/z*: 161.081 (M⁺+1), 144.095 (10.56 %), 129.06 (19.88 %); HRMS Calcd for C₆H₁₂N₂O₃: 160.08; Found: 160.17.

(±)-5-(2,2-Dimethyl-[1,3]dioxolan-4-yl)-3H-[1,3,4]oxadiazole-2-thione(8). The hydrazide **7** (300 mg, 0.30 mol) was dissolved in absolute ethanol and CS₂ (3 ml, 0.05 moles) and KOH (1.8 g, 0.3 moles in H₂O, 20 mL) were added. The reaction mixture was heated under reflux with an aid of magnetic stirring for 3 h, during that time the colour of the solution turned to yellow (H₂S evolution took place during the reaction time. TLC (CHCl₃ / MeOH, 6:4), Rf: 0.65). Ethanol was distilled off under reduced pressure and the residue was dissolved in H₂O, acidified with HCl to pH=2 and extracted with EtOAc (3 x 20 mL). The combined extracts were evaporated to dryness under vacuum to give crystalline solid **8** (0.275 g, 82 %), mp 165-167 °C. IR cm⁻¹: 1675 (C=N), 1150 (C-O-C), 1280 (C=S). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 1.42 (m, 6H, 2CH₃), 3.90 (d, 2H, OC-CH₂), 3.93 (s, 1H, OC-CH), 7.01 (s, 1H, NH). MS *m/z*: 203.041 (M⁺+1), 170.07 (16.39 %), 156.021 (23.29 %), 127.65 (37.24 %); HRMS Calcd for C₇H₁₀N₂O₃S: 202.041; found: 202.231.

Potassium,(±)-2,2-dimethyl-[1,3]dioxolan-4-carboxylic-acid-hydrazide-thio-semi-carbazinate (9). The hydrazide **7** (150 mg, 0.15 mmol) and carbon disulfide (0.60 mL, 0.15 mmol) were added to a solution containing KOH (560 mg, in 50 mL) and ethanol (50 mL). The mixture was heated under reflux for 5 h (TLC (CHCl₃ / MeOH, 6:4), Rf: 0.70). The solvent was evaporated to dryness under reduced pressure to give a yellowish solid, which was dissolved in H₂O (300 mL). The solution was acidified with conc. HCl to give a white precipitate, filtered and washed with EtOH. The precipitate recrystallized from chloroform/ethanol to give white needles of the salt **9** (120 mg, 79%), mp 196-197 °C. IR showed bands at 3258 cm⁻¹ (OCNH), 1580 cm⁻¹ (NH), and 1238 cm⁻¹ (C=S). ¹H NMR (250 MHz, TMS) δ (ppm) 1.40 (m, 6H, 2CH₃), 2.00 (s, 1H, NH), 4.14(d, 2H, OC-CH₂), 4.84 (s, 1H, OC-CH), 8.00 (s, 1H, OC-NH); MS *m/z*: 259.015 (M⁺+1), 202.909 (21.66 %); HRMS Calcd for C₇H₁₁KN₂O₄S: 258.011; Found: 258.340.

(±)-2,2-Dimethyl-[1,3]dioxolan-4-carboxylic-acid-hydrazide-thioformamido-semi-carbazide (10). The hydrazide **7** (160 mg, 0.01 mol) was added to ammonium thiocyanate (0.01 mol) in dry benzene (10 mL) and the mixture was heated under reflux for 6 h (TLC (CHCl₃ / MeOH, 6:4), Rf: 0.60). The solid material obtained on cooling was filtered and recrystallized from methanol (0.58 g, 85 %), mp 145-147 °C. IR cm⁻¹: 3100 (NH), 1665 (CON), 1280 (C=S). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 1.41 (m, 6H, 2CH₃), 2.00 (s, 1H, -NH), 2.04 (s, 2H, -NH₂) 4.14 (s, 2H, OCH₂), 4.84 (s, 1H, OCH), 8.01 (s, 1H, N-NH). MS *m/z*: 220.071 (M⁺+1), 203.049 (7.73 %), 172.152 (21.17 %), 159.256 (27.63 %), 144.689 (34.25 %), 129.152 (41.31%); HRMS Calcd for C₇H₁₃N₃O₃S: 219.071; found :219.263.

(±)-5-(2,2-Dimethyl-[1,3]dioxolan-4-yl)-4H-[1,2,4]triazole-3-thiol (**11**). The compound **10** (220 mg, 10 mmol) in 2N-NaOH solution (40 mg NaOH, 10 mmol in 100 mL H₂O) was heated under reflux for 5 h. (TLC (CHCl₃/MeOH, 6:4); Rf: 0.55). After cooling, the solution was made acidic with conc. HCl and the precipitate was then recrystallized from absolute ethanol to give crystalline fibres **11** (295 mg, 84 %). IR cm⁻¹: 3200 (NH), 2860-2760 (S-H), 1670 (C=N). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 1.41 (m, 6H, 2CH₃), 3.00 (s, 1H, C-SH), 3.63 (s, 1H, C-NH), 4.19 (s, 2H, O-CH₂), 5.18 (s, 1H, O-CH), MS *m/z*: 202.057 (M⁺+1), 168.084 (16.84 %), 101.061 (49.98 %); HRMS Calcd for C₇H₁₁N₃O₂S: 201.057; found :201.246.

1, 2:5, 6-di-O-isopropylidene-D-mannitol (15). D-Mannitol (**14**) (1.5 g, 0.01 mol) in acetone (60 mL) was added to ZnCl₂ (2 g, 0.015 mol). The mixture was stirred vigorously at 20 °C for 3 h (TLC (C₆H₆/CHCl₃, 4:6) showed the development of one spot Rf: 0.56). Aqueous K₂CO₃ solution (14 mL, containing 1.52 g, 0.011 mol) was added gradually with the aid of stirring, then filtered and washed with Et₂O/Me₂CO (1:1) (20 mL). Ether (60 mL) was added to the combined filtrate and washing. The ether layer was separated and the aqueous layer was again extracted two times with Et₂O (10 mL, each time). The combined organic layer dried over MgSO₄, filtered and evaporated to dryness under vacuum reduced pressure at room temperature to give **15** as white crystals (210 mg, 75%), m.p. 117°C, (lit., 119°C).¹¹

2,3-O-isopropylidene-D-glyceraldehyde (3a). 1,2:5,6-Di-O-isopropylidene-D-mannitol **15** (260 mg, 0.001 mol), in dry THF (5 mL) and freshly prepared Pb(OAc)₄ (543 mg, 0.001 mol) were mixed vigorously for 0.5 h at an ice bath, then for another 0.5 hr at room temperature. TLC (C₆H₆/CHCl₃, 4:6), Rf: 0.80. The reaction mixture was filtered and washed with THF (1 mL). The THF evaporated down to dryness under vacuum on a warm water bath (50°C) to give a light syrup of 2,3-O-isopropylidene-D-glyceraldehyde **3** (221 mg, 85%), α_D²⁰ = +1.6. IR showed a band at 2936 cm⁻¹ (=C-H), 1750 cm⁻¹ (>C=O), 1082 cm⁻¹ (C-O-C). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 1.41 (m, 6H, 2CH₃), 4.19 (d, 2H, OC-CH₂), 4.76 (s, 1H, OC-CH), 9.72 (s, 2H, O=CH₂), MS *m/z*: 131.064 (M⁺+1), 114.068 (13.02 %), 101.064 (22.93 %); HRMS Calcd for C₆H₁₀O₃: 130.064; found: 130.145

2,3-O-isopropylidene-D-glyceric acid (16). 2,3-O-isopropylidene-D-glyceraldehyde (**3a**) was oxidized with KMnO₄/KOH as described for the oxidation of (±)-(2,2-Dimethyl-[1,3]dioxolan-4-carbaldehyde (**3**). TLC (benzene/ chloroform, 3:7), Rf: 0.17. The reaction mixture give a white solid, which was recrystallized from light petroleum ether to give colorless needles (0.15 g, 68%), mp. 68°C; IR exhibited bands at 2500 cm⁻¹ (OH) and 1710 cm⁻¹ (>C=O). ¹H NMR (250 MHz, TMS) δ (ppm) 1.41 (m, 6H, 2CH₃), 4.13 (d, 2H, OC-CH₂), 4.76 (s, 1H, OC-CH), 11.0 (s, 1H, COOH); MS *m/z*: 147.051 (M⁺+1), 129.065 (12.23%), 114.068 (22.43 %), 101.068 (31.27 %); HRMS Calcd for C₆H₁₀O₄: 146.058; Found: 146.141.

D-Xylitol (20). D-Xylose (**19**) (6.00 g.) was dissolved in methanol (40 mL) and the NaBH₄ (1.2 g) was added in small portions after each production of gas had ceased. The temperature of the reaction mixture was allowed to rise to slightly above 50°C. At the end of the additions, the reaction mixture was allowed to stand for an additional 1 h with continuous stirring (TLC (C₆H₆/MeOH, 7:3), Rf = 0.41 was observed). BIO-RAD (Dowex 50WX8) resin was added

slowly until the production of gas ceased. The mixture was filtered and the filtrate was evaporated to dryness to give yellow syrup. The latter was dissolved in methanol and evaporated to remove boric acid in the form of volatile methyl borate. The crude D-xylitol (**20**) (6.0 g, 98%) was a colorless syrup, crystallized by standing and recrystallized from EtOH/H₂O to give crystalline xylitol (**20**) (5.5 g, 90.4%); m.p.100-105 °C (lit 102 °C). ¹¹ IR exhibited bands at 2500 cm⁻¹ (OH) and 3645 cm⁻¹ (OH),1075 cm⁻¹ (CH₂-OH). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 2.00 (s, 1H, C-OH), 3.37(s, 1H, C-CH), 3.38 (s, 1H, C-CH), 3.68 (d, 2H, C-CH₂);MS *m/z*: 153.05 (M⁺+1), 135.074 (11.75 %),118.06 (22.86 %); HRMS Calcd for C₅H₁₂O₅: 152.05; Found: 152.15

(Tetrahydro-[1,3]dioxino[5,4-*d*][1,3]dioxin-4-yl)-methanol (21). D-Xylitol **20** (5.0 g) was dissolved in a mixture of formaldehyde (37 %, 1 ml) and conc. HCl (1.0 mL) and maintained at 50°C for 2 days. The reaction mixture was cooled to room temperature, extracted with CHCl₃ (6 x 5 ml), dried over anhydrous MgSO₄, filtered and evaporated to dryness then absorbed on a column of silica gel (eluent, Benzene/MeOH, 8:2). The product **21** was isolated as colourless needles (1.25 g, 26.5%), m.p.124 °C. IR cm⁻¹: 3450 (OH), 1075 cm⁻¹ (CH₂-OH), 800(C-O-C). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 2.00 (s, 1H, -OH), 3.01 (s, 1H, OC-CH), 3.66 (d, 2H, OC-CH₂), 3.93(d, 2H, OC-CH₂), 4.20 (s, 1H, OC-CH), 4.47 (s, 1H, OC-CH), 4.70 (d, 2H, OC-CH₂).MS *m/z*: 177.07 (M⁺+1), 159.07(10.17 %), 145.05 (18.18 %); HRMS Calcd for C₇H₁₂O₅: 176.07; Found: 176.17

Tetrahydro-[1,3]dioxino[5,4-*d*][1,3]dioxin-4-carboxylic acid (22). 2,4:3,5-*O*-dimethylene-xylitol (**21**) was oxidized with KMnO₄ / KOH as described in the oxidation of (±)-2,3-*O*-isopropylidene glycerol (**2**) to give 2,4:3,5-*O*-dimethylene xylitolic acid (**22**) as colorless needles (5.5 g, 90.4%);m.p.100-105 °C. IR exhibited bands at 3645 cm⁻¹ (OH), 1710 (>COOH), 1075 (CH₂-OH). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 3.34 (s, 1H, OC-CH), 3.93(d, 2H, OC-CH₂), 4.44 (s, 1H, OC-CH), 4.70 (d, 2H, OC-CH₂), 4.99 (s, 1H, OC-CH), 11.00(s, 1H, -COOH).MS *m/z*: 191.05 (M⁺+1), 173.04 (9.43 %), 159.047 (16.75 %),146.065 (23.55 %); HRMS Calcd for C₇H₁₀O₆: 190.05; Found: 190.15

Deprotection of compounds 8, 11, 17, 18, 23, and 24. ¹⁴ Small quantities (0.1 g) of each compounds **8, 11, 17, 18, 23,** and **24** were added to ethanol (95%, 5 mL) and heated under reflux for 3 h in the presence of Amberlyst 15 (wet) ion-exchange resin (0.01 g) The reaction mixture, cooled to room temperature, was filtered, and evaporated to dryness to give the products 5-(1,2-Dihydroxy-ethyl)-3*H*-[1,3,4]oxadiazole-2-thione (**12**) (0.08 g) , 1-(5-Mercapto-4*H*-[1,2,4]triazole-3-yl)-ethane-1,2-diol (**13**) (0.07 g), respectively.

5-(1,2-Dihydroxy-ethyl)-3*H*-[1,3,4]oxadiazole-2-thione(12). Recrystallized from EtOAc/Hex to give a colorless needles (0.08 g; 82 %); m.p 165-167 °C; TLC (CHCl₃ / MeOH, 6:4), R_f: 0.65; IR cm⁻¹: 3400 (OH), 3250 (N-H), 1676 (C=N), 1304-1251 (C=S), 1157 (C-O-C). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 2.01 (d, 2H, 2OH), 3.33(s, 1H, OC-CH), 3.73 (d, 2H, OC-CH₂), 7.02 (s, 1H, C-NH). MS *m/z*: 163.017 (M⁺+1), 145.012 (11.04 %), 128.01 (21.47 %), 100.098 (38.68 %); HRMS Calcd for C₄H₆N₂O₃S: 162.01; Found: 162.17.

1-(5-Mercapto-4H-[1,2,4]triazole-3-yl)-ethane-1,2-diol (13). Recrystallized from CH₂Cl₂/Hex to give pink crystals (0.07 g, 82 %); m.p 135-137 °C; TLC (CHCl₃ / MeOH, 6:4), Rf: 0.65; IR cm⁻¹: 3300 (OH), 3200 (NH), 2861-2780 (SH), 1672 (C=N). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 2.01 (d, 2H, 2OH), 3.00(s, 1H, -SH), 4.01 (d, 2H, OC-CH₂), 4.59 (s, 1H, OC-CH). MS *m/z*: 162.03 (M⁺+1), 144.012 (11.66 %), 127.01 (22.07 %), 100.00 (38.66 %); HRMS Calcd for C₄H₇N₃O₂S: 161.03; Found: 161.18.

5-(1,2-Dihydroxy-ethyl)-3H-[1,3,4]oxadiazole-2-thione (17a). Recrystallized from EtOAc/Hex to give colorless needles (0.064 g, 64 %); m.p 165-167 °C; TLC (CHCl₃ / MeOH, 6:4), Rf: 0.65; IR cm⁻¹: 3400 (OH), 3250 (N-H), 1676 (C=N), 1304-1251 (C=S), 1157 (C-O-C). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 2.01 (d, 2H, 2OH), 3.33(s, 1H, OC-CH), 3.73 (d, 2H, OC-CH₂), 7.02 (s, 1H, C-NH). MS *m/z*: 163.017 (M⁺+1), 145.012 (11.04 %), 128.01 (21.47 %), 100.098 (38.68 %); HRMS Calcd for C₄H₆N₂O₃S: 162.01; Found: 162.17

1-(5-Mercapto-4H-[1,2,4]triazole-3-yl)-ethane-1,2-diol (18a). Recrystallized from CH₂Cl₂/Hex to give pink crystals (0.056 g, 56 %); m.p 135-137 °C; TLC (CHCl₃ / MeOH, 6:4), Rf: 0.65; IR cm⁻¹: 3300 (OH), 3200 (NH), 2861-2780 (SH), 1672 (C=N). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 2.01 (d, 2H, 2OH), 3.00(s, 1H, -SH), 4.01 (d, 2H, OC-CH₂), 4.59 (s, 1H, OC-CH). MS *m/z*: 162.03 (M⁺+1), 144.012 (11.66 %), 127.01 (22.07 %), 100.00 (38.66 %); HRMS Calcd for C₄H₇N₃O₂S: 161.03; Found: 161.18.

5-(1,2,3,4-Tetrahydroxy-butyl)-3H-[1,3,4]oxadiazole-2-thione (23a). Recrystallized from EtOAc/Hex to give white crystals (0.069 g, 69 %) ; m.p 163-165 °C; TLC (CHCl₃ / MeOH, 6:4), Rf: 0.65; IR exhibited bands at 3645 cm⁻¹ (OH), 3215 (NH), 1075 (CH₂-OH). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 2.01 (m, 4H, 4OH), 3.30(s, 1H, OC-CH), 3.38 (s, 1H, OC-CH), 3.40 (s, 1H, OC-CH), 3.68 (d, 2H, OC-CH₂), 7.01(s, 1H, -NH). MS *m/z*: 223.03 (M⁺+1), 205.032 (8.07 %), 191.032 (14.34 %), 160.023 (28.25 %), 99.096 (55.57 %); HRMS Calcd for C₆H₁₀N₂O₅S: 222.03; Found: 222.25.

1-(5-Mercapto-4H-[1,2,4]triazole-3-yl)-butane-1,2,3,4-tetraol (24a). Recrystallized from CH₂Cl₂/Hex to give pale yellow crystals (0.058 g, 58 %) ; m.p 133-136°C; TLC (CHCl₃ / MeOH, 6:4), Rf: 0.65; IR cm⁻¹: 3300 (OH), 3200 (NH), 2860-2760 (SH), 1672 (C=N). ¹H NMR (250 MHz, DMSO-d₆) δ (ppm) 2.01 (m, 4H, 4OH), 3.00(s, 1H, C-SH), 3.38 (s, 1H, OC-CH), 3.63(s, 1H, -NH), 3.68 (s, 2H, OC-CH₂), 3.76 (s, 1H, OC-CH), 4.58 (s, 1H, OC-CH). MS *m/z*: 222.03 (M⁺+1), 204.042 (8.10 %), 157.04 (29.27 %), 170.043 (23.41 %), 100.096 (54.95 %); HRMS Calcd for C₆H₁₁N₃O₄S: 221.03; Found: 221.25

Acknowledgements

We are grateful to Dr. G. Gosselin (Director of UMR 5625 CNRS-Univ.MontpellierII. France) for hospitality to (MB) and we are also thankful to Prof. C. Perigaud and Dr. D. Egron for providing chemicals and useful discussions.

References

1. Awad, L. F.; El Ashry, E. S. H. *Carbohydrate Res.* **1998**, *312*, 9.
2. Awad, L. F.; El Ashry, E. S. H. *Nucleosides and Nucleotides.* **1999**, *18*, 557.
3. El Sayad, A. *Acta. Chim. Slov.* **2005**, *52*, 429.
4. Al Massoudi, N. *Bull. Soc. Chim. Belgium.* **1997**, *106*, 215.
5. (a) El Ashry, E. S. H.; El Kilany, Y. In *Advances in Heterocyclic Chemistry*, Katritzky, A. R.; Ed., Academic Press: New York, 1996, Vol. 67, p 391. (b) El Ashry, E. S. H.; El Kilany, Y. In *Advances in Heterocyclic Chemistry*, Katritzky, A. R., Eds., Academic Press: New York, 1997, Vol. 68, p 1. (c) El Ashry, E.S.H. ; El Kilany, Y. In *Advances in Heterocyclic Chemistry*, Katritzky, A. R., Eds., Academic Press: New York, 1998, Vol. 69, p 129.
6. (a) Hill, J. In *Comprehensive Heterocyclic Chemistry*, Katritzky, A. R. ; Rees, C.W.; Eds., Pergamon: Oxford, 1984; Vol. 6(B) p 445. (b) Demirbas, N. *Turk .J. Chem.* **2005**, *29*, 125. (c) Amir, M.; Shikha, K. *Eur .J. Med. Chem.* **2004**, *39*, 535.
7. (a) Polya, J. B. In *Comprehensive Heterocyclic Chemistry*, Katritzky, A. R.; Rees, C. W.; Eds., Pergamon: Oxford 1984, Vol. 6(B), p 787. (b) El Ashry, E. S. H.; Awad, L. F.; Winkler, M. *J. Chem. Soc, Perkin Trans. 1* **2000**, 829. (c) Demirbas, N.; Alpy-Karaoglu, S.; Demirbas, A. ; Sancak, K. *Eur .J. Med. Chem.* **2004**, *39*, 793.
8. Moslat, A.; Abbasoud, M. *Pol. J. Pharmacol.* **2002**, *54*, 55.
9. Zamani, K. *Turk. J. Chem.* **2003**, *27*, 119.
10. Cansiz, A.; Koparir, M.; Demirdag, A. *Molecules* **2004**, *9*, 204.
11. Vogel, A. I. *Vogel's Text book of Practical Organic Chemistry*, 5th Edn, Wiley: New York, 1989; p 654
12. Othman, A. A.; Al.Timari, U. *Tetrahedron* **1980**, *36*, 753.
13. Perroll, M.; Newman, M. S. In *Organic Synthesis*, Ed., Wiley: New York ,1955, Vol 3, p 502.
14. Che Chul, Y.; Youn-sik, L. *Bull. Korean Chem. Soc.* **2003**, *24*, 1229.