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Synthesis of Four New Brassinosteroids Analogues 11-Oxo-Functionalized on C Ring, with 24-Nor Side Chain and Containing 5 β -Cholanic Acid Skeleton

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Abstract

In this work, I report the synthesis of four new brassinosteroids analogues with 24-*nor* side chain and 11-oxo functionalized on C ring, containing 5β-cholanic acid skeleton: *3α, 12β-diacetoxy-22(S), 23-dihydroxy-24-nor-5β-cholan-11-one (**20**)*; *3α, 12β, 22(S), 23-tetrahydroxy-24-nor-5β-cholan-11-one (**21**)*; *3α, 12β, 22(S), 23-tetraacetoxy-24-nor-5β-cholan-11-one (**22**)* and *3α, 12β-diacetoxy-[2,2-dimethyl-22(S), 23-dioxolane]-24-nor-5β-cholan-11-one (**23**)* derivatives from commercial deoxycholic acid.

Keywords: Brassinosteroids; C-functionalized; 24-nor side chain

Introduction

Brassinosteroids (Brs) are a naturally occurring steroidal plant hormones group that regulates plant growth and development by producing an array of physiological changes. Brs occur at low concentrations throughout the plant kingdom. They have been detected in all plant organs (pollen, anthers, seeds, leaves, stems, roots, flowers, and grains) and also in the insect and crown galls [1,2]. Further work has demonstrated that Brs not only induce stem elongation but also increase biomass and total crop yield. Moreover, Brs are recognized to have an ameliorative role in plants subjected to various biotic and abiotic stresses, such as high temperature [3], heavy metals excess [4,5], salinity [6], water stress [7,8] and extreme temperatures [9]. Several authors and mainly Hayat et al. have reported structure-activity relationships (SAR) of brassinosteroid [10]. These SAR are based on the functions contained in the A, B ring, A/B ring fusion and in the side chain. However, in recent decades, efforts have been focused on the synthesis of new brassinosteroid analogues, keeping common patterns of organic functions in the A/B rings and *cis-trans* fusion between these, as in some natural brassinosteroids, but with dramatic structural changes in the side chain (shorter side chains, different oxygenated functions, spirostanic, aromatic and cyclic substituents, esters, carboxylic acids, etc.) and oxygenated functions in C ring. Surprisingly these analogs have presented very important biological activities. On the other hand, the isolation of natural brassinosteroids with oxygenated function in ring C has not been reported. However, the synthesis of this type of analogs is very important for SAR studies of this kind of phytohormone. In this direction, hecogenin (**1**) is an abundantly available steroidal sapogenin, used as raw material in the production of a large number of Brs spirostanic analogs with oxygenated function in ring C [11-21]. Examples of brassinosteroid analogues oxo-functionalized in C ring are shown in Figure 1. Others active Brs C- oxo and oxa functionalized analogs (**6**-**8**) bearing a cholanic acid skeleton were derived from cholic acids [22]. Nevertheless, C-functionalized analogs **9**-**16** (Figure 2) were obtained from deoxycholic acid [23-25]. The plant growth-promoting activity of compounds **9** and **13** was tested in the hypocotiles elongation and cothyledons expansion of radish bioassay, where the compound **9** showed growth promoting activity at 10^{-5} mg/mL concentration in both bioassays, whereas compound **13** showed inhibiter effect in the cothyledons expansion test at the same concentration [24]. Compound **14** showed an increase of 38.6% by weight at 10^{-5} mg/mL concentration in cotyledons expansion of radish bioassay [25]. In this work is reported the synthesis and structural determination of four new Brs analogues, obtained from deoxycholic acid, with a cis-A/B ring junction, 24-*nor* side chain and 11-oxo-12β-hydroxyl/acetate function on C ring containing with 5β-cholanic acid skeleton.

Materials and Methods

General

All reagents were purchased from commercial suppliers and used without further purification (Merck, Darmstadt, Germany or Aldrich, St. Louis, MO, USA). Melting points were measured on a Stuart-Scientific SMP3 apparatus (Staffordshire, ST15 OSA, UK) and are uncorrected. Optical rotations were obtained for $CHCl_3$ or CH_3OH, solutions on a Perkin-Elmer 241 polarimeter (Wellesley, Massachusetts, USA) and their concentrations are expressed in g/100 mL. NMR spectra were recorded on a Bruker AM-200 (Bruker, Rheinstetten, Germany) spectrometer operating at 200.1 MHz for ^1H and 50.3 MHz for ^{13}C. Chemical shifts are expressed in ppm downfield relative to TMS (δ scale) in $CDC1_3$ solutions and coupling constants (J) are given in hertz. Carbon multiplicity were established by a DEPT pulse sequence. IR spectra were recorder as KBr disks in a Bruker FT-IR Vector-22 (Bruker, Germany) and frequencies are in cm^{-1}. Elemental analyses were obtained on a Fisons-Carlo-Erba EA-1108 Automost microanalyzer (Fisons Instruments/Carlo-Erba Instruments, Milano, Italy) For analytical TLC, Merck silica gel 60 in 0.25 mm layer was used and TLC spots were detected by heating after spraying with 25% H_2SO_4 in H_2O. Chromatographic separations were carried out by conventional column on Merck silica gel 60 (230-400 Mesh) using hexane-EtOAc gradients of increasing polarity. All organic extracts were dried over anhydrous magnesium sulfate and evaporated under reduced pressure, below 40°C.

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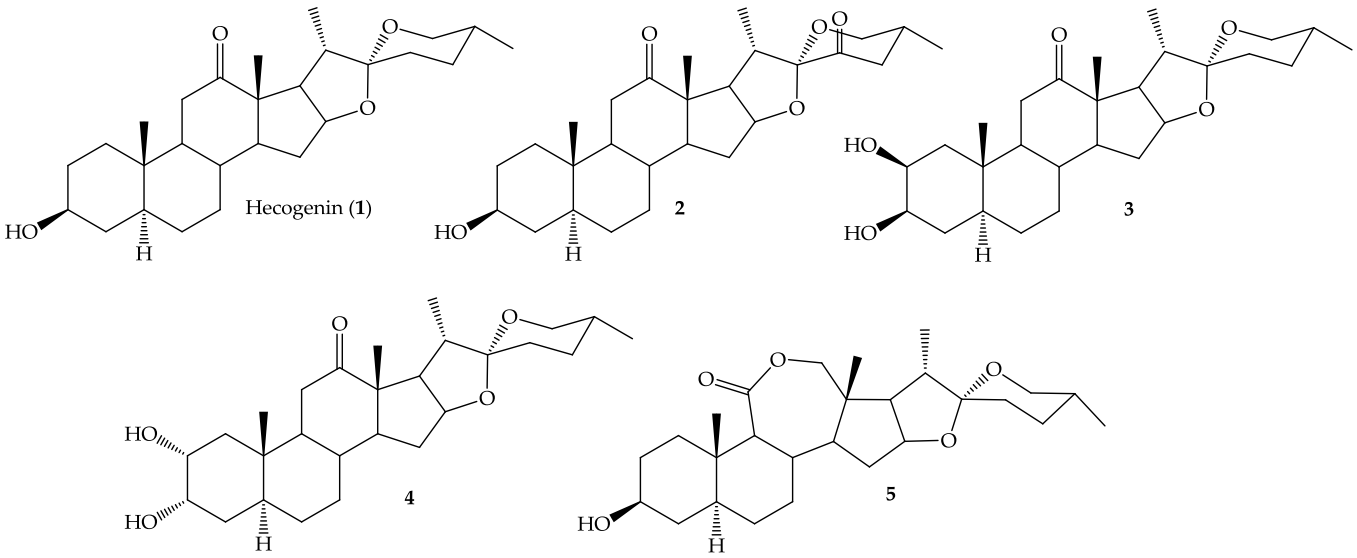


Figure 1: Structure of hecogenin (**1**) and some Brs spirostanic synthetic analogs (**2**-**5**), with oxygenated function in ring C.

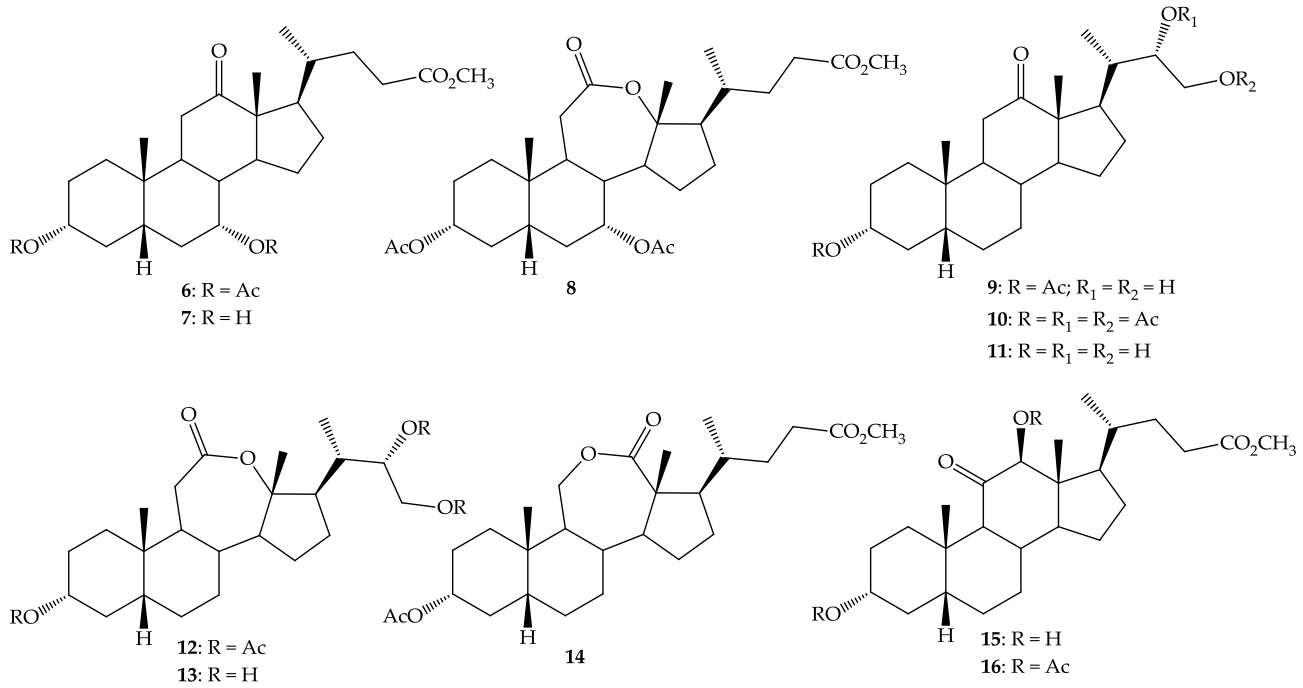


Figure 2: Structure of 12-oxo (**6**-**7**) and 12-oxa (**8**) functionalized active Brs analogs bearing a cholanic acid skeleton and 12-oxa and 11-oxa C-functionalized (**12**-**14**), 11-oxo-12β-hydroxy (**15**) and 11-oxo-12β-acetoxy (**16**) deoxycholic acid derivative.

Synthesis

*24-oic 3α, 12β-diacetoxy-11-oxo-5β-cholan acid (**17**)*

A solution of **16** (3.2 g, 7.61 mmol) and K_2CO_3 (0.8 g, 7.55 mmol) in MeOH (150 mL) was stirred at room temperature for 1.5 h. The end of the reaction was verified by TLC. Then the solvent was removed (until a 40 mL approximate volume) and the residue acidified with 2% HCl (15 mL) and extracted with EtOAc (3 × 20 mL). The organic layer was washed with 5% $NaHCO_3$ (30 mL) and water (2 × 15 mL), dried over Na_2SO_4, and filtered. The solvent was evaporated under reduced pressure. The crude was re-dissolved in CH_2Cl_2 (5 mL) and chromatographed on silica gel with petroleum ether/EtOAc mixtures of increasing polarity (19.8:0.2→10.2:9.8). Compound **17** (3.17 g, 85% yield) was as a colorless solid: m.p. 85.5-91.7°C (MeOH/Et_2O); $[\alpha]_D^{25}$+46.2° (c=0.405, $CHCl_3$); **IR**: 3432-2516; 1735; 1243; 1028. **^{1}H NMR**: 0.69 (s, 3H, H-18); 0.93 (d, *J*=6.3 Hz, 3H, H-21); 1.16 (s, 3H, H-19);

2.02 (s, 3H, CH_3CO); 2.15 (s, 3H, CH_3CO); 2.35 (m, 2H, H-23); 2.49 (d, *J*=10.6 Hz, 1H, H-9); 4.70 (m, 1H, H-3); 4.90 (s, 1H, H-12). Elemental analysis: found C, 68.22%; H, 8.57%; $C_{28}H_{42}O_7$ requires C, 68.54%; H, 8.63%.

*3α, 12β-diacetoxy-24-nor-5β-cholan-22-en-11-one (**18**)*

To a solution of **17** (3.42 g, 7.69 mmol) in anhydrous benzene (300 mL) were added $Cu(OAc)_2$ (0.25 g, 1.38 mmol) and pyridine (1.0 mL). Then refluxed and $Pb(OAc)_4$ (8.34 g, 18.81 mmol) was added in four portions at hourly intervals. After the addition was completed, the reaction was continued for 1 h. The end of reaction was verified by TLC, and then the mixture was filtered and the solvent was evaporated under reduced pressure. The crude was re-dissolved in CH_2Cl_2 (5 mL) and chromatographed on silica gel with petroleum ether/EtOAc mixtures of increasing polarity (19.8:0.2→16.4:3.6). Compound **18** (2.24 g, 72.3% yield) was obtained as a colorless solid: m.p. 170.9-172.8°C (hexane/Et_2O); $[\alpha]_D^{25}$+64.8° (c=0.466, $CHCl_3$); **IR**: 3069; 1732; 1723; 1637; 1450; 1364; 1237; 1029; 910. **^{1}H NMR**: 0.66 (s, 3H, H-18); 0.99 (d, *J*=6.9 Hz, 3H, H-21); 1.16 (s, 3H, H-19); 2.02 (s, 3H, CH_3CO); 2.18 (s, 3H, CH_3CO); 2.46 (m, 2H, H-1 and H-20); 2.48 (d, *J*=10.2 Hz, 1H, H-9); 4.70 (m, 1H, H-3); 4.90 (dd, *J*=10.1 and 2.1 Hz, 1H, H-23); 4.92 (s, 1H, H-12); 4.95 (ddd, *J*=17.1, 2.1 and 0.8 Hz, 1H, H-23); 5.77 (ddd, *J*=17.1, 10.1 and 8.8 Hz, 1H, H-22). Elemental analysis: found C, 72.87%; H, 9.13%; $C_{27}H_{40}O_5$ requires C, 72.94%; H, 9.07%.

*3α, 12β-dihydroxy-24-nor-5β-cholan-22-en-11-one (**19**)*

To a solution of **18** (1.58 g, 3.55 mmol) in MeOH (60 mL) was added K_2CO_3 (0.79 g, 7.54 mmol), then the suspension was stirred at room temperature for 6 h. The end of the reaction was verified by TLC. Then the solvent was removed (until a 10 mL approximate volume) and the residue acidified with 2% HCl (10 mL) and extracted with EtOAc (2 × 20 mL). The organic layer was washed with 5% $NaHCO_3$ (20 mL) and water (2 × 10 mL), dried over Na_2SO_4, and filtered. The solvent was evaporated under reduced pressure. The crude was re-dissolved in CH_2Cl_2 (5 mL) and chromatographed on silica gel with petroleum ether/EtOAc mixtures of increasing polarity (19.8:0.2→13.8:6.2). Compound **19** (1.26 g, 98% yield) was as a colorless solid: m.p. 120.3-121.2°C (MeOH/Et_2O); $[\alpha]_D^{25}$+61.4° (c=0.44, $CHCl_3$); **IR**: 3490; 3258; 3066; 1709; 1638; 1453; 1020; 922; 906. **^{1}H NMR**: 0.43 (s, 3H, H-18); 1.06 (d, *J*=6.9 Hz, 3H, H-21); 1.13 (s, 3H, H-19); 2.43 (m, 1H, H-1α); 2.55 (m, 1H, H-20); 3.57 (m, 1H, H-3); 3.84 (s, 1H, H-12); 4.82 (dd, *J*=10.2 and 2.2 Hz, 1H, H-23); 4.91 (ddd, *J*=17.1, 2.2 and 0.8 Hz, 1H, H-23); 5.73 (ddd, *J*=17.1, 10.2 and 8.7 Hz, 1H, H-22). Elemental analysis: found C, 76.49%; H, 10.15%; $C_{23}H_{36}O_3$ requires C, 76.62%; H, 10.06%.

*3α, 12β-diacetoxy-22(S), 23-dihydroxy-24-nor-5β-cholan-11-one (**20**)*

To a solution of alkene **18** (2.05 g, 4.28 mmol) in acetone (150 mL) was added NMO (0.45 g, 3.84 mmol). Then the mixture was homogenized by magnetic stirring and 1.5 mL of 4% OsO_4 (0.157 mmol) were added dropwise with stirring for 12 h at room temperature. The end of the reaction was verified by TLC. Then the solvent was removed (until a 25 mL approximate volume) and water (25 mL) and $Na_2S_2O_3.5H_2O$ (25 mL saturated solution) were added. The organic layer was extracted with EtOAc (2 × 30 mL), washed with water (2 × 50 mL), dried over Na_2SO_4, and filtered. The solvent was evaporated under reduced pressure. The crude was re-dissolved in CH_2Cl_2 (5 mL) and chromatographed on silica gel with petroleum ether/EtOAc mixtures of increasing polarity (19.8:0.2→15.6:4.4), by subsequent recrystallization (MeOH/Et_2O) compound **20** was obtained as a colorless solid (1.50 g, 68% yield): m.p. 183.7-186.6°C (MeOH/Et_2O); $[\alpha]_D^{25}$+27.6° (c=0.156, $CHCl_3$); **IR**: 3423; 1747; 1723; 1248; 1026. **^{1}H NMR**: 0.67 (s, 3H, H-18); 0.91 (d, *J*=6.3 Hz, 3H, H-21); 1.15 (s, 3H, H-19); 2.00 (s, 3H, CH_3CO); 2.14 (s, 3H, CH_3CO); 2.47 (d, *J*=11.1 Hz, 1H, H-9); 3.47 (m, 1H, H-23); 3.63 (m, 1H, H-23); 3.72 (m, 1H, H-22); 4.68 (m, 1H, H-3); 4.88 (s, 1H, H-12). Elemental analysis: found C, 67.60%; H, 8.87%; $C_{27}H_{42}O_7$ requires C, 67.75%; H, 8.85%.

*3α, 12β, 22(S), 23-tetrahydroxy-24-nor-5β-cholan-11-one (**21**)*

To a solution of **20** (0.07 g, 0.146 mmol) in MeOH (50 mL) was added K_2CO_3 (0.035 g, 0.215 mmol), then the suspension was stirred at room temperature for 6 h. The end of the reaction was verified by TLC. Then the solvent was removed (until a 10 mL approximate volume) and the residue acidified with 2% HCl (2 mL) and extracted with EtOAc (2 × 10 mL). The organic layer was washed with 5% $NaHCO_3$ (10 mL) and water (2 × 10 mL), dried over Na_2SO_4, and filtered. The solvent was evaporated under reduced pressure. Subsequent recrystallization (MeOH/Et_2O) gave compound **21** (0.0485 g, 84.1% yield) which it was identified as a colorless solid: m.p. 152.8-154°C (MeOH/Et_2O); $[\alpha]_D^{25}$+99.5° (c=0.20, MeOH); **IR**: 3428; 1700; 1066; 1022. Elemental analysis: found C, 69.71%; H, 9.61%; $C_{23}H_{38}O_5$ requires C, 70.02%; H, 9.71%.

*3α, 12β, 22(S), 23-tetraacetoxy-24-nor-5β-cholan-11-one (**22**)*

Compound **20** (0.09 g, 0.188 mmol) was dissolved in CH_2Cl_2 (30 mL) and pyridine (3.0 mL). Later 4-*N,N*-dimethylaminopyridine (DMAP, 5 mg) and Ac_2O (3 mL) were added to the solution. The end of the reaction was verified by TLC (2 h), and then the solvent was reduced to a volume about 5 mL, extracted with EtOAc (2 × 10 mL). The organic layer was washed with 5% $KHSO_4$ (2 × 5 mL) and water (2 × 10 mL), dried over Na_2SO_4 and filtered. The solvent was evaporated under reduced pressure. The crude was redissolved in CH_2Cl_2 (3 mL) and chromatographed on silica gel with petroleum ether/EtOAc mixtures of increasing polarity (19.8:0.2 → 14.2:5.8), to yield pure **20** (0.09 g, 85.1% yield) as a colorless solid: m.p. 78.1-79.5°C (hexane/EtOAc); $[\alpha]_D^{25}$+41.5° (c=0.412, $CHCl_3$); **IR**: 1740; 1451; 1370; 1243; 1028. **^{1}H NMR**: 0.65 (s, 3H, H-18); 0.99 (d, *J*=6.7 Hz, 3H, H-21); 1.15 (s, 3H, H-19); 2.01 (s, 3H, CH_3CO); 2.04 (s, 3H, CH_3CO); 2.07 (s, 3H, CH_3CO); 2.14 (s, 3H, CH_3CO); 2.50 (d, *J*=11.1 Hz, 1H, H-9); 3.97 (dd, *J*=12.1 and 9.0 Hz, 1H, H-23); 4.29 (dd, *J*=12.1 and 2.0 Hz, 1H, H-23); 4.69 (m, 1H, H-3); 4.85 (s, 1H, H-12); 5.14 (m, 1H, H-22). Elemental analysis: found C, 66.10%; H, 8.13%; $C_{31}H_{46}O_9$ requires C, 66.17%; H, 8.24%.

*3α, 12β-diacetoxy-[2,2-dimethyl-22(S), 23-dioxolane]-24-nor-5β-cholan-11-one (**23**)*

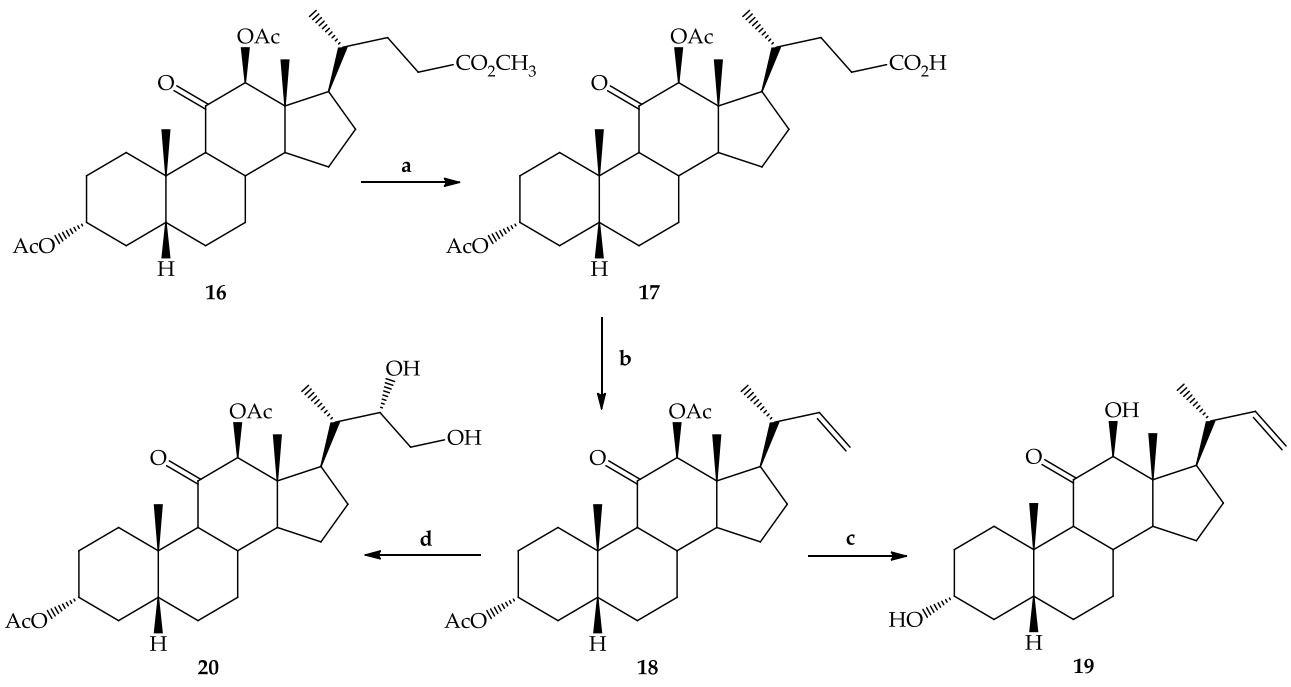
To a solution of **20** (0.08 g, 0.167 mmol) in dry acetone (50 mL) was added anhydrous $CuSO_4$ (0.250 g, 1.57 mmol), then the suspension was stirred in N_2 atmosphere at room temperature for 5 days. The end of the reaction was verified by TLC. Then the mixture was filtered and the solvent was evaporated under reduced pressure. The crude was re-dissolved in CH_2Cl_2 (3 mL) and chromatographed on silica gel with petroleum ether/EtOAc mixtures of increasing polarity (19.8:0.2→16.8:3.2) to yield pure **23** (0.06 g, 69.2% yield) as a colorless oil; $[\alpha]_D^{25}$+32.5° (c=0.520, $CHCl_3$); **IR**: 1734; 1699; 1245; 1066; 1030. **^{1}H NMR**: 0.67 (s, 3H, H-18); 0.85 (d, *J*=6.9 Hz, 3H, H-21); 1.13 (s, 3H, H-19); 1.29 (s, 3H, O_2CCH_3); 1.36 (s, 3H, O_2CCH_3); 2.01 (s, 3H, CH_3CO); 2.14 (s, 3H, CH_3CO); 2.45 (m, 1H, H-9); 3.53 (dd, *J*=7.8 Hz and 7.8 Hz, 1H, H-23); 3.89 (dd, *J*=7.8 and 6.3 Hz, 1H, H-23); 4.07 (m, 1H, H-22); 4.67 (m, 1H, H-3); 4.89 (s, 1H, H-12). Elemental analysis: found C, 69.50%; H, 8.97%; $C_{30}H_{46}O_7$ requires C, 69.47%; H, 8.94%.

Results and Discussion

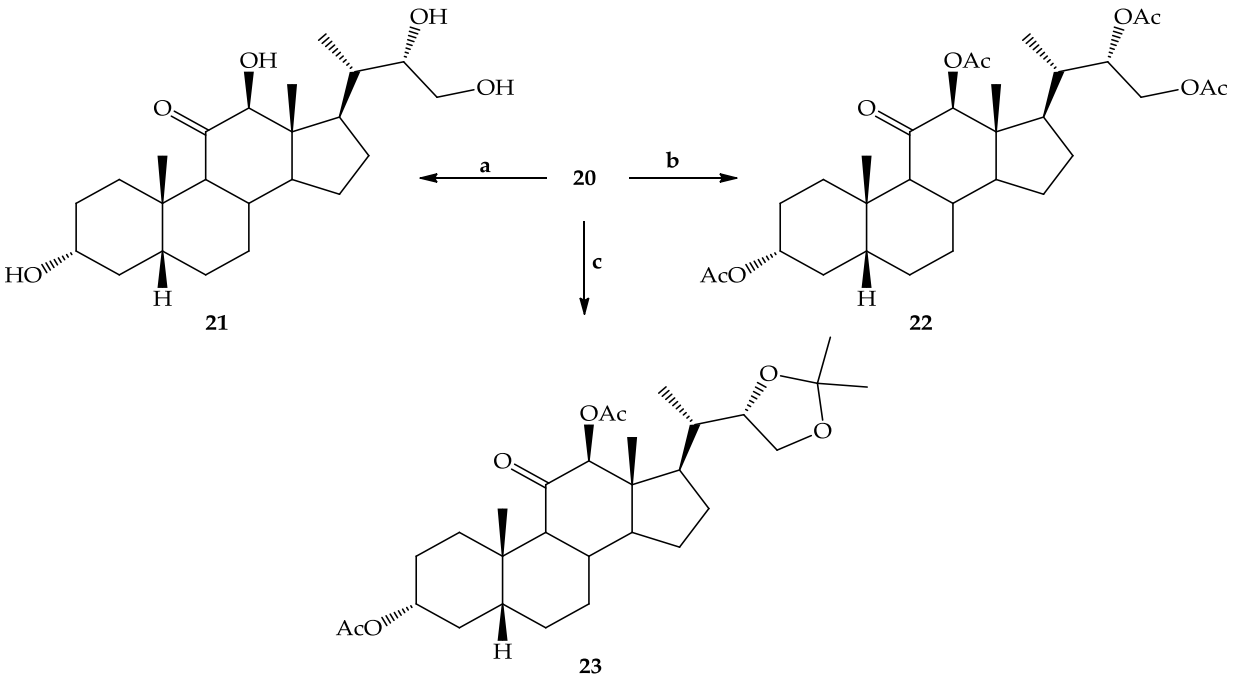
Previously we have reported the synthesis, and structural determination, of compounds **15** and **16** from deoxycholic acid [25]. Selective saponification of **16** in K_2CO_3/MeOH at room temperature afforded acid **17** with 85% yield (Scheme 1). The presence of the carboxylic function was confirmed by the signal at δ_C=179.27 ppm in ^{13}C NMR spectrum (see Table 1). The olefinic intermediate **18** (Scheme 1) was obtained with 72.3% yield by decarboxylation reaction of **17** in $Pb(OAc)_4/Cu(AcO)_2$ system, as reported for the preparation of other derivatives [24,26-28]. The presence of terminal exocyclic double bond was confirmed by the signals observed in the ^{1}H NMR spectrum at δ_H=4.90 ppm (dd, *J*=10.1 and 2.1 Hz, 1H, H-23); 4.95 ppm (ddd, *J*=17.1, 2.1 and 0.8 Hz, 1H, H-23) and 5.77 ppm (ddd, *J*=17.1, 10.1 and 8.8 Hz, 1H, H-22). While two signals at δ_C=113.36 and 142.79 ppm were observed in the ^{13}C NMR, assigned to at C-22 and C-23 respectively (see Table 1). Saponification of olefin **18** under mild conditions (K_2CO_3/MeOH at room temperature for six hours) produces the ketol **19** with 98% yield (Scheme 1) The presence of two signals at δ_H=3.57 ppm (m, 1H) and δ_H=3.84 ppm (s, 1H) in the ^{1}H NMR spectrum confirms the removal of acetate groups. These carbinolic hydrogens were assigned as H-C3 and H-C12, respectively, according to their observed hydrogen multiplicities. The next step was the dihydroxylation reaction of olefin **18**, however, some authors have reported that the electrophilic reactions at the steroidal C-22 double bond with OsO_4, $RuCl_3/NaIO_4$, Prevost-Woodward reaction with I_2/AgOAc produces predominantly (*S*) configuration at C-22 [29-31]. Then treatment of the alkene **18**, with catalytic OsO_4 in NMO and purification of reaction crude by C.C. and subsequent crystallization, afforded compound **20** with 68% yield (Scheme 1). The presence of three carbinolic proton signals at δ_H=3.47 ppm (m, 1H); 3.63 ppm (m, 1H) and 3.72 ppm (m, 1H) in the ^{1}H NMR spectrum that were assigned to the hydrogens H-23a, H-23b and H-22, respectively by 2D heteronuclear correlations with C-23 and C-22 and ^{13}C DEPT-135 experiment. The configuration at C-22 was established as (*S*) considering referential aspects for this reaction and comparing NMR spectroscopic data for similar compounds previously reported by us for other derivatives [23,24]. The new derivatives **21**, **22** and **23** were prepared from compound **20**, according to Scheme 2. Compound **21** was obtained by treatment of **20** under mild saponification conditions (K_2CO_3/MeOH, r.t.) with 84.1% yield, whereas standard acetylation (Ac_2O/DMAP/CH_2Cl_2) of compound **20** produces the tetra-acetylated derivative **22** with 85.1% yield. ^{1}H NMR spectroscopic evidence indicates the presence of four singlets signals at δ_H=2.01, 2.04, 2.07 and 2.14 ppm (3H, CH_3CO each), while six signals at δ_C=20.86, 20.90, 21.25, 21.40, 169.94, 2 x 170.46 and 170.94, ppm were observed in ^{13}C NMR (Table 1), so confirming the presence of four acetate groups in the molecule. Finally, by ketalization reaction of **20** with $(CH_3)_2CO/CuSO_4$ anhydrous system, the ketal derivative **23** was obtained with 69.2% yield, according to the methodology previously described. In the ^{1}H NMR spectrum of compound **23** two singlets signals at δ_H=1.29 and 1.36 ppm were observed, these were assigned to the methyl of acetonide group [$O_2C(CH_3)_2$]. While in the ^{13}C NMR spectrum, the signals observed at δ_C=25.33 (CCH_3), 26.39 (CCH_3) and 108.30 ppm [$O_2C(CH_3)_2$], confirming the presence of acetonide group.

Conclusions

We have designed a synthetic sequence, which allows the obtainment of three new synthetic derivatives (compounds **17**-**19**) from commercial deoxycholic acid and four new brassinosteroids analogues (compounds **20**-**23**) with 24-*nor* side chain, oxygenated function at C-22 (*S*) and C-23 and 11-oxo functionalized on C ring, containing 5β-cholanic acid skeleton. Bioassays in Rice Lamina Inclination Test (RLIT) and growth in *Arabidopsis thaliana*, to detect possible biological activity of compounds **20**-**23,** are under being developed and these results will be reported later.



Scheme 1: Synthetic route developed for intermediates **17**-**19** and Brs analog **20**. Conditions and reagents: **a**. K_2CO_3/MeOH, r.t. 1.5 h, 85%. **b**. $Pb(OAc)_4/Cu(OAc)_2$/C_6H_6, reflux, 2.5 h, 72.3%. **c**. K_2CO_3/MeOH, r.t. 6 h, 98%. **d**. OsO_4 4%, $(CH_3)_2CO$/NMO, r.t. 12 h, 68%.



Scheme 2: Synthetic route developed for Brs analog **21**-**23**. Conditions and reagents: **a**. K_2CO_3/MeOH, r.t. 6 h, 84.1%. **b**. Ac_2O/DMAP/py/CH_2Cl_2, 2 h, 85.1%. **c**. $CuSO_4$/$(CH_3)_2CO$, r.t. 5 days, 69.2%.

C	17	18	19	20	22	23
1	33.94	33.94	36.21	33.89	33.88	33.90
2	27.02	27.01	30.99	27.29	26.99	26.97
3	73.76	73.72	71.05	73.75	73.66	73.68
4	32.31	32.31	34.21	32.25	32.26	32.26
5	42.40	42.41	42.46	42.34	42.33	42.36
6	26.71	26.69	26.67	26.99	27.75	26.67
7	26.34	26.35	26.51	26.99	26.71	26.29
8	36.40	36.49	36.97	36.28	36.17	35.49
9	50.21	50.14	49.83	50.07	50.02	50.06
10	34.14	34.14	33.99	34.07	34.05	34.08
11	203.99	204.01	211.80	203.88	203.54	203.81
12	85.89	85.90	84.12	85.31	85.11	85.46
13	50.10	50.05	52.45	50.34	50.48	50.07
14	55.90	55.40	55.89	53.17	54.10	53.65
15	24.97	24.50	24.60	26.28	26.27	25.99
16	23.17	23.25	23.30	26.70	23.18	23.24
17	53.97	54.01	52.45	54.01	53.09	54.23
18	9.76	10.03	8.83	9.33	9.09	9.53
19	23.14	23.14	23.23	23.18	23.15	23.14
20	32.52	38.65	38.08	37.97	37.01	36.56
21	20.48	22.24	22.22	14.71	14.46	15.58
22	29.32	142.79	143.46	74.00	74.17	77.93
23	31.98	113.36	112.84	63.50	62.56	66.53
24	179.27	-	-	-	-	-
$\underline{C}H_3CO$	20.77	20.80	-	20.93	20.90	20.81
$CH_3\underline{C}O$	170.64	170.50	-	170.69	170.94	170.51
$\underline{C}H_3CO$	21.41	21.34	-	21.43	21.40	21.37
$CH_3\underline{C}O$	170.23	170.18	-	170.29	170.46	170.12
$\underline{C}H_3CO$	-	-	-	-	20.86	-
$CH_3\underline{C}O$	-	-	-	-	169.94	-
$\underline{C}H_3CO$	-	-	-	-	21.25	-
$CH_3\underline{C}O$	-	-	-	-	170.46	-
$OC\underline{C}H_3$	-	-	-	-	-	26.39
$OC\underline{C}H_3$	-	-	-	-	-	25.33
$O_2\underline{C}(CH_3)_2$	-	-	-	-	-	108.30

Table 1: δ ^{13}C NMR ($CDCl_3$, 50.3 MHz) for compounds **17**-**20** and **22**-**23**.

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