the UV spectrum in the 210–400 nm region. NMR spectrum, (ppm): 1.08, 1.17, 1.62, and 1.98 (3H each, singlets, Me_{12}, Me_4, Me_8, and $OCOCH_3$, respectively), 2.82 (1H, multiplet, H_{6a}), 4.45 (1H, doublet of doublets, J = 2 and 8 Hz, H_4), 5.3 (1H, multiplet, H_7), 5.38 (2H, singlet, H_2 and H_3).

The same acetate was obtained similarly from the mixture of products formed from the diepoxide (X) when it was chromatographed on air-dry silica gel.

SUMMARY

1. It has been established that the epoxidation of cembrene with perbenzoic and peracetic acids takes place stereospecifically at each of the trisubstituted double bonds with the formation of 4S,5R-, 7S,8S-, and 11S,12S-monoepoxycembrenes, the structures and absolute configurations of which have been established by spectral methods.

2. Epoxidation of cembrene at the $C_{11}-C_{12}$ double bonds under the conditions used takes place preferentially as compared with epoxidation at the C_7-C_8 double bond.

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WITHANOLIDES OF Physalis

I. PHYSALACTONE

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UDC 547.926

The first results of a chemical study of Physalis alkekengi L. were published more than a century ago [1] when a bitter substance, which was called physalin, was isolated from the leaves of this plant. No structural investigations were carried out at that time. Beginning only in 1969 have communications appeared on the chemical structure of the steroid compounds contained in Physalis; in particular, physalins A [2], B [3], and C [4], having the structure of 13,14-seco-16,24-cyclosteroids, have been found (collected in Japan) in P. alkekengi var. Franchetti. In addition to those mentioned, withaphysalins A, B, and C have been isolated from Ph. minima [5], withaphysacarpin from Ph. ixocarpa Brot. [6], and withanolide B and 4β-hydroxywithanolide E from Ph. peruviana [7, 8].

Different chemotypes of the same plant species contain withanolides differing from one another by their chemical structure and amount [9, 10] and therefore we considered it desirable to study the withano-

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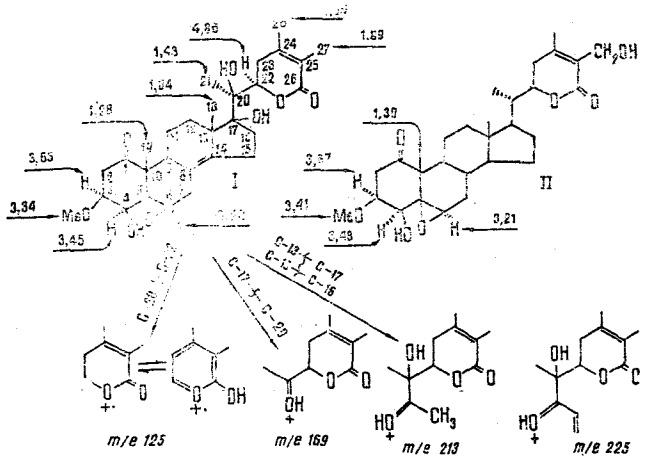
lide composition of Ph. alkekengi collected in the flowering phase in the foothills of the kopet-Dagh in the valley of the R. Sumbar (village of Kara-Kala, Turkmen SSR).

From the epigeal part we isolated a withanolide with the composition $C_{29}H_{40}O_8$, which we have called physalactone. The presence in the spectra of physalactone of a maximum at $\lambda_{max}^{C_2H_5OH}$ 228 nm (log ε 3.94) and strong bands at ν_{max}^{KBr} 1100 cm^{-1} (C–O–C) and 1690 and 1710 cm^{-1} (α, β-unsaturated lactone and cyclic ketone), the presence of the maximum fragment with m/e 125 in the mass spectrum, and the appearance of five three-proton singlets at δ 1.04, 1.28, 1.43, 1.89, and 1.95 in the NMR spectrum permitted the assumption that this substance belonged to the withanolide group [11].

The small long-wave shift of the maximum in the UV spectrum and the comparatively small molecular extinction coefficient indicates that ring A is saturated.

The presence in the mass spectrum of physalactone of ions with m/e 347 and 169 (cleavage between C-17 and C-20) and ions with m/e 303 and 213 (cleavage between C-13 and C-17 and simultaneously between C-15 and C-16), in addition to the ion with m/e 125, the presence of which in withanolides shows that there is an unsaturated lactone ring in the side chain, establishes the positions of two hydroxy groups at C-17 and C-20. A three-proton singlet at δ 1.43 (21-CH_3) and a one-proton triplet at δ 4.86 (22-H) confirm the presence of an OH group at C-20.

In the NMR spectrum of physalactone there is the signal of a methoxy group at δ 3.34. Ions with m/e 516 (M^+), 484 (M – 32), 391 (M – 125), and 347 (M – 169) for the withanolide itself and the analogous ions for its acetate [M^+ 558, m/e 466 (M – 60 – 32), 433 (M – 125), 389 (M – 169)] show that the methoxy group and one acetyl group are present in the steroid part of the molecule.



Attention is merited by the fact that the chemical shifts of the protons in ring A and B of physalactone agree well with the chemical shifts of 3-methoxy-2,3-dihydrowithaferin A (II) [12] (Scheme). This compound was obtained by heating withaferin A in a methanolic solution of p-toluenesulfonic acid.

The magnitudes of the signal for the C-4 and C-6 protons (δ 3.45 and 3.20, respectively) also confirm the 4β-hydroxy-5β,6β-epoxy configuration of this part of the molecule. In the opposite case, i.e., with the 4α-hydroxy-5α,6α-epoxy configuration, as has been shown on model compounds of the cholestane series [13], the signal of the C-4 proton would have δ 3.98 and the C-6 proton δ 3.63. Thus, the structures of rings A and B and of the oxygen-containing functions in these rings are completely identical for physalactone (I) and for 3-methoxy-2,3-dihydrowithaferin A.

The UV spectrum of the new withanolide has, in addition to absorption at 228 nm, another maximum at 205 nm (log ε 3.87), which reflects the presence of an isolated ditertiary double bond. The most probable position of this bond between C-8 and C-14 is shown by the presence in the mass spectrum of physalactone of ions with m/e 303 (fragment of the steroid part) and 213 (fragment with the lacone ring), and the absence of an ion with m/e 225 (see Scheme). The existence of a $\Delta^{8(14)}$ bond makes cleavage between C-14 and C-15 impossible for physalactone.

All this has enabled us to put forward for physalactone the structure 4β,17,20α(R)-trihydroxy-3-methoxy-1-oxo-5β,6β-epoxy-22R-witha-8(14),24-dienolide (I). The R configuration at C-22 is based on the circular dicroism curve (D_{247} = 14,200, Δε + 4.3). The nomenclature at C-20 is given in accordance with Fieser's symbols [14].

The question naturally arises of whether physalactone is a native product, since 3-methoxy-2,3-dihydrowithaferin A (II) was first isolated directly from Withania somnifera [12, 15], but Lavie et al. came to the conclusion that the conditions for its isolation could lead to the addition of methanol to the Δ^2 double bond. The mild conditions for the isolation of physalactone are evidence in favor of its native nature.

EXPERIMENTAL

For thin-layer chromatography (TLC) we used type KSK silica gel containing 5% of gypsum in the benzene–chloroform–methanol (5 : 5 : 1) system. The revealing agent was a saturated chloroform solution of $SbCl_3$ (with heating). The UV spectrum was taken on a Specord UV-Vis spectrophotometer, the IR spectrum on a UR-20 instrument, the mass spectra on a MKh-1303 mass spectrometer at an ionizing voltage of 40 eV, and the NMR spectrum on a JNM-4H-100/100 MHz instrument with HMDS (in this paper, the signals have been recalculated to TMS). The solvent was $CDCl_3$.

Isolation of Physalactone. The comminuted air-dry epigeal part of the plant (3 kg) was covered with cold water and the mixture was heated to the boil. The hot mass was pressed out through linen, and the plant material was again covered with cold water and heated. The combined aqueous extract was reextracted with chloroform. After the solvent had been distilled off, 14 g (0.46%) of a light green powder was obtained.

The powder (5 g) was chromatographed on a column containing 400 g of silica gel. Elution was carried out with mixtures of equal volumes of chloroform and benzene containing amounts of methanol gradually increasing from 1 to 5%. Fractions with a volume of 300 ml were collected and were examined by TLC. Fractions 43-51 (0.7 g) contained mainly one compound showing a bright pink color on TLC. After rechromatography, 0.5 g (0.016% of the weight of the plant) of amorphous physalactone was obtained. Composition $C_{29}H_{40}O_8$, $[\alpha]_D^{20}$ –4.3° (c 2.9, methanol), $\lambda_{max}^{C_2H_5OH}$ 205 (ε 7500), 228 nm (ε 7000), ν_{max}^{KBr} 3400, 1710, 1690, 1100 cm^{-1}. Mass spectrum m/e: 516 (0.6%), M^+; 484 (2%), M–32; 466 (7%), 484–H_2O; 448 (10%), 466–H_2O; 430 (2.5%), 448–H_2O; 391 (9%), M–125; 363 (5.5%), 391–H_2O; 359 (5%), M–125–32; 347 (4.5%), M–169; 341 (4%), 359–H_2O; 326 (3.5%), 347–H_2O; 303 (5%), M–213; 213 (14%); 169 (32%), 152 (74%); 125 (100%). NMR, δ: 1.04 s (3H); 1.28 s (3H); 1.43 s (3H); 1.89 s (3H); 1.95 s (3H); 3.20 t (1H); 3.34 s (3H); 3.45 d (1H); 3.63 m (1H); 4.86 t (1H).

Physalactone 4-O-Acetate. A mixture of 0.5 g of the withanolide, 1 ml of pyridine, and 1 ml of acetic anhydride was left at room temperature for a day. Then the solvents were evaporated off in vacuum, the residue was dissolved in 1 ml of methanol, and the solution was poured onto ice. After recrystallization from aqueous methanol the acetate had mp 170-172°C; empirical formula $C_{31}H_{42}O_9$. ν_{max}^{KBr} 3400, 1730, 1710, 1690, 1235, 1100 cm^{-1}. Mass spectrum: m/e 558 (2.5%) M^+; 540 (1%), M–H_2O; 522 (2.5%), M–$2H_2O$; 498 (1%), M–60; 480 (1%), 498–H_2O; 466 (6%), 498–32; 462 (4%), 498–$2H_2O$; 448 (24%), 466–H_2O; 433 (20%), M–125; 415 (2%), 433–H_2O; 401 (6.5%), 433–32; 389 (9%), M–169; 383 (8.5%), 401–H_2O. The NMR spectrum was similar to that of physalactone A, with the exception of the proton at C-4, which was shifted downfield (δ 4.57).

SUMMARY

1. A new withanolide, which has been called physalactone, has been isolated from Physalis alkekengi L. growing in Turkmenia. It has the structure of 4β,17,20α(R)-trihydroxy-3-methoxy-1-oxo-5β,6β-epoxy-22R-witha-8(14),24-dienolide.

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STEROID SAPONINS AND SAPOGENINS OF Allium

X. NEOAGIGENIN 6-O-BENZOATE FROM Allium turcomanicum

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UDC 547.926+547.918

Continuing a systematic study of the steroid spirostans of plants of the genus Allium [1], we have investigated A. turcomanicum Rgl. The present paper gives information on the steroid sapogenins of the epigeal part of this plant.

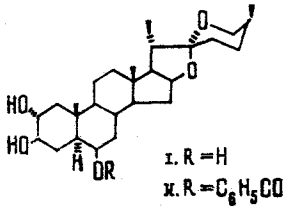
From the total sapogenins obtained by the hydrolysis of the extractive compounds we isolated the known genins yuccagenin, neoagigenin, alliogenin, and 2α,3α-dihydroxy-(25S)-5α-spirostan-6-one. This is the first time that the last-mentioned compound, which we have called neoagigenone, has been isolated from plants. It has been obtained previously by the selective oxidation of neoagigenin [2].

From the same combined product we obtained a new steroid sapogenin (II) with the composition $C_{34}H_{48}O_6$. Judging from the ratio of the intensities of the absorptions bands in the IR spectrum at 930 cm^{-1} (strong) and 900 cm^{-1} (weak), the genin (II) must be assigned to the steroid spirostans of the 25S series [3, 4]. The existence of ester absorption at 1720 and 1280 cm^{-1} and of frequencies relating to a benzene ring (1600, 1585, and 718 cm^{-1}) permit the assumption that the molecule of the sapogenin (II) contains an ester grouping of aromatic character.

The nature of this grouping is shown by the mass spectrum of compound (II) in which, together with ions characteristic for spirostan sapogenins there are strong peaks of ions with m/e 122 ($C_7H_6O_2$) and 105 (C_7H_5O) characteristic of benzoic acid.

When the sapogenin (II) was subjected to alkaline saponification, the neutral fraction was found to contain neoagigenin (I), and benzoic acid was identified by TLC in the acid fraction of the hydrolyzate.

The facts given show that the spirostan (II) is a neoagigenin benzoate. The NMR spectrum of the sapogenin (II) has a one-proton signal with $W_{1/2}$ = 6 Hz at δ 5.16 belonging to an equatorial proton geminal to a benzoate group, and therefore the benzoic acid must have esterified the hydroxyl at C-6.



I. R = H
II. R = C_6H_5CO

The proposed structure is confirmed by the preparation of the spirostan (II) from neoagigenin (I). For this purpose, neoagigenin was converted by benzoylation into the tribenzoate which, without being isolated in the pure form, was subjected to selective saponification. The neoagigenin 6-O-benzoate isolated from the reaction products was identical in melting point, specific rotation, and spectral properties, with the sapogenin (II) isolated from the plant raw material.

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