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CHIRAL BUTENOLIDES AS DIENOPHILES IN DIELS-ALDER CYCLOADDITIONS

R. M. Ortuño, J. Corbera and J. Font*

Departament de Química Orgânica, Facultat de Ciências, Universitat Autònoma de Barcelona,
Bellaterra (Barcelona), Spain.

Summary.- Differently substituted chiral butenolides, prepared from D-ribonolactone, react with butadiene at 210° affording enantiomerically pure bicycloadducts as single diastereoisomers, in good yields. The ability of protoanemonin (formed in some pyrolytic reaction conditions) to react regiospecifically at the exocyclic double bond, to give spirolactones, is shown.

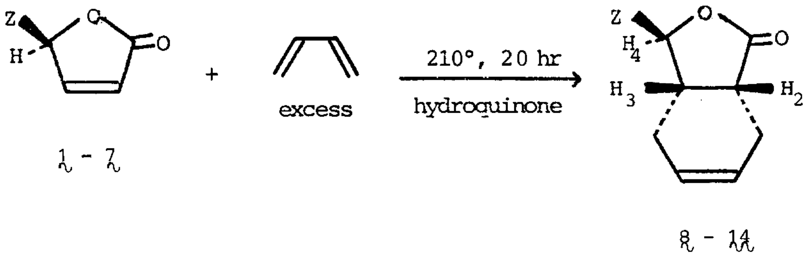
The Diels-Alder cycloaddition remains today one of the most powerful synthetic methods. It provides a cyclic skeleton with a latent functionality, since the resulting double bond can be transformed into other functional groups. On the other hand, the creation of chiral centers in such cycloadditions is controlled by the rules of orbital symmetry conservation and their absolute configuration can be determined by another chiral center already present in one of the reactants[1].

The conjugate double bond of an α,β-butenolide has scarcely been utilized as a dienophile in Diels-Alder type reactions and there are only a few examples reported in the literature[2-7]. The recent communication by Mann and Thomas[7] prompted us to publish our results in this field. These authors have reported a reaction catalyzed by $AlCl_3$ between a chiral butenolide (Z= $CH_2OSiPh_2{}^tBu$, (Scheme 1), prepared from D-ribonolactone) and butadiene at 55°, one week, affording the corresponding adduct in 75 % yield.

Our purpose was to make a study on the general behaviour of several optically active α,β-butenolides, differently substituted at the C-4 position, with dienes in Diels-Alder cycloadditions. We report herein our results on their reaction with butadiene, and some particular experiments with furan and cyclopentadiene.

Thus, treatment of butenolides 3 and 4 (Scheme 1 and Table 1) with furan at several temperatures gave no reaction. Addition of a catalytic amount of $SnCl_4$ at r.t. led to formation of decomposition products. Reaction of lactone 5 with cyclopentadiene at 100° gave a mixture of diastereoisomeric tricyclic adducts in 77 % yield.

However, reaction between butadiene and the dienophiles listed on Table 1 at 210° for 20 hours, in the presence of hydroquinone, gave the adducts 8 - 14 in a single isomeric form (HPLC, ^{13}C NMR), and in good yields. (Scheme 1). The bicyclic compounds 9 - 14 have three chiral centers and suitable functional groups to be transformed into interesting products. For example, the adduct **9**, from (±)-β-angelica lactone, **2**, was used[2] in its racemic form as a precursor of prostaglandins PG_2 and Mann and Thomas have prepared a prostacyclin analogue and chrisanthemic acids from a similar cycloadduct[7].



Scheme 1

Table 1. Cycloaddition of several butenolides with butadiene

Entry	Butenolide		Adduct[a]	$\{\alpha\}_D^{20}$ ($CHCl_3$)	b.p.(°C/torr)[b]	% Yield[c]
(1)	Z = H [d]	**1**	**8**	----	80/0.05	62
(2)	CH_3[8]	**2**	**9**	- 25.64 (c=1.46)	90/0.08	70[e]
(3)	CH_2OH[9]	**3**	**10**	- 6.50 (c=2.87	160/0.04	32
(4)	CH_2OAc[9]	**4**	**11**	+ 6.82 (c=2.03)	120/0.05	53
(5)	CH_2OMe[9]	**5**	**12**	+ 2.60 (c=2.40)	110/0.04	77
(6)	CH_2OBn[9]	**6**	**13**	+ 5.66 (c=1.74)	160/0.05	80
(7)	CH_2SPh[8]	**7**	**14**	- 0.20 (c=1.97)	175/0.04	66

[a] All new compounds gave satisfactory elemental analysis.

[b] External temperature given.

[c] Calculated on the unrecovered starting material.

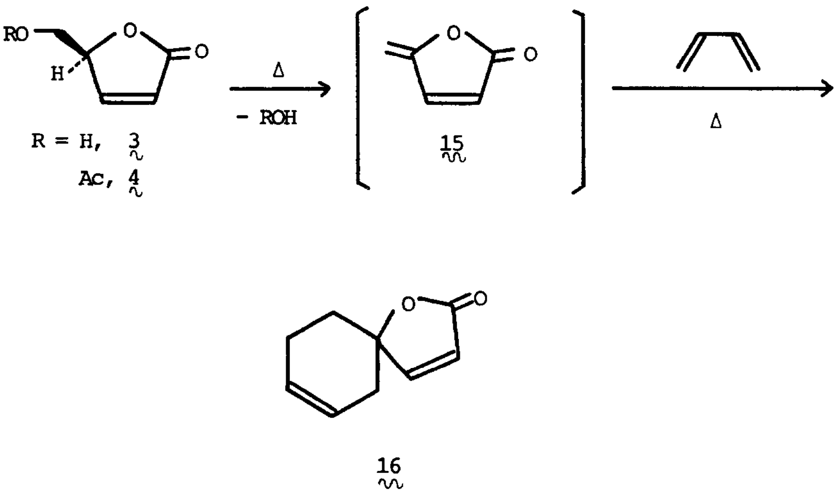
[d] Formula are referred to Scheme 1.

[e] Best yield reported, from racemic material[2].

The optically active butenolides **2** - **7** were prepared from D-ribonolactone by methods previously described by us[8,9].

The stereochemistry of the adducts was determined from their ^{1}H NMR spectra and results from the interaction of butadiene with the less hindered side of the conjugate double bond of the butanolides in the TS. Indeed, in adducts 9 - 14 the coupling constants H_3-H_4 (Scheme 1) are ∿4 Hz and this value agrees with a trans relationship for these protons showing the attack of butadiene opposite to the Z substituent, the nature of Z seeming not to have any influence over the diastereofacial selectivity of the reaction.

In general, adducts were obtained in good yields except in the reactions of 3 and 4 (Table 1) that gave bicycloadducts 10 and 11 in lower yields, although in both cases the spiroadduct 16, m.p. 65-66°, was obtained in 25 % and 16 % yields, respectively, as a by-product. Such a compound results from the regiospecific cycloaddition of butadiene with the exo double bond of protoanemonin, 15, that is formed in the pyrolytic conditions (Scheme 2). The ability of protoanemonin to give 16 has been confirmed when 15[10] was made to react with butadiene at 180°, affording 16 in 34 % yield. Although reactions of protoanemonin with nucleophiles have been widely explored[8,11], this behaviour of 15 as a selective dienophile had never published previously and it is being investigated in order to have an easy acces to spirolactones. These are interesting and versatile molecules that can be used, for instance, in the preparation of some spiroethers with olfactory properties as natural aromas[12].



Scheme 2

Further studies are being carried out in our laboratory on the reactions of α,β-butenolides with other dienes and catalysts. Synthetic applications of chiral bicycloadducts are also under investigation.

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References and notes

1. For a recent review on asymmetric Diels-Alder reactions see: W. Oppolzer, *Angew. Chem. Int. Ed. Engl.* **23**, 876 (1984).
2. D. Taub, Z. Zelawski and N. L. Wender, *Tetrahedron Lett.* **1970**,3667.
3. C. H. Kuo, D. Taub and N. L. Wender, *Tetrahedron Lett.* **1972**, 5317.
4. T. R. Hoye, A. J. Caruso and A. S. Magee, *J. Org. Chem.* **47**, 4152, (1982).
5. H. J. Liu, E. N. C. Browne and P. R. Pednekar, *Canad. J. Chem.* **60**, 921 (1982).
6. S. D. Burke, D. R. Maguin, J. A. Oplinger, J. P. Baker and A. Abelmagid, *Tetrahedron Lett.* **25**, 19 (1984).
7. J. Mann and A. Thomas, *J. Chem. Soc. Chem. Commun.* **1985**, 737.
8. P. Camps, J. Corbera, J. Cardellach, J. Font, R. M. Ortuño and O. Ponsatí, *Tetrahedron*, **39**, 395 (1983).
9. a) P. Camps, J. Font and O. Ponsatí, *Tetrahedron Lett.* **22**, 1471 (1981); b) P. Camps, J. Cardellach, J. Font, R. M. Ortuño and O. Ponsatí, *Tetrahedron*, **38**, 2395 (1982). The optical rotation of γ-benzyloxymethyl-α,β-butenolide, **6**, given in these two papers is wrong due to a typographic error in the original manuscripts. The true value is $\{\alpha\}^{20}_{D}=-107$ (c=1.6, EtOH).
10. Prepared from β-acetylacrylic acid: Ch. Grundmann and E. Kober, *J. Amer. Chem. Soc.* **77**, 2332 (1955).
11. a) A. Calderón, J. Font and R. M. Ortuño, *Tetrahedron*, **40**, 3787 (1984); b) J. Bigorra, J. Font, C. Jaime, R. M. Ortuño and F. Sánchez-Ferrando, *Tetrahedron*, in press; c) J. Bigorra, J. Font, R. M. Ortuño, F. Sánchez-Ferrando, F. Florencio, S. Martínez-Carrera and S. García-Blanco, *Tetrahedron*, in press.
12. B. Buchmann, H. Marshall-Weyerstahl and P. Weyerstahl, *Tetrahedron*, **40**, 3393 (1984).

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