way to that for **5a**: **6** → **7b**, 95%; **7b** → **8b**, 81%; **8b** → **10b**, 35% with 25% recovery of **8b**; **10b** → **5b**, 44%. Differently from **5a**, however, the compound **5b** was obtained as a mixture of *E* and *Z* isomers (ca. 3:1).

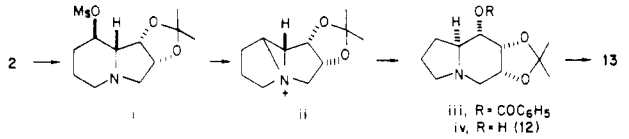
On treatment of **5b** using 10 equiv of $NaBH_4$ in the same way as described for the preparation of **4a** and **2**, the desired product **2** was obtained as expected in 32% total yield[10] and identified with the sample described above. This reaction, however, was found to coproduce the compound **12** (mp 85–86 °C, 23%), which was formed probably by attack of the amino group to the active allyl carbon (e.g., in **5c**) prior to the reduction of the conjugated ester group. These products were easily separated by simple silica gel chromatography in the yields described, respectively. The compounds **2** and **12** obtained here could be derived to **1** and its isomer **13** [mp 166–168 °C, $[\alpha]^{25}_D$ −36.3° (*c* 0.49, H_2O), 58%],[11,12] respectively.

The present synthesis of swainsonine constitutes a strategically new approach for the construction of the indolizidine ring system of the swainsonine type and also proves useful in the total synthesis of this class of alkaloids.[13] Moreover, this synthesis involves the attractive features of utilizing sodium borohydride for reducing the conjugated esters and the lactams, claiming new utility values of this reagent.

Supplementary Material Available: Experimental details of compounds prepared (10 pages). Ordering information is given on any current masthead page.

(10) Attempts for improving the yield of **2** and the ratio of **2** to **13** were not carried out at this stage.

(11) The structure of **13** was assigned on the basis of its spectral data and further confirmed by identification with the sample derived from **2** (1. mesylation of **2** to i; 2. conversion of i by treatment with $C_6H_5CO_2Na$ to iii via ii; 3. alkaline hydrolysis of iii to iv; 4. acid treatment of iv to **13**). Details will be reported separately.



(12) The mitogenic activity and the mannosidase inhibitory activity of **13** were somewhat weaker than those of **1**.

(13) Very recently, we have completed the synthesis of (+)-castanospermine, which will be reported in due course.

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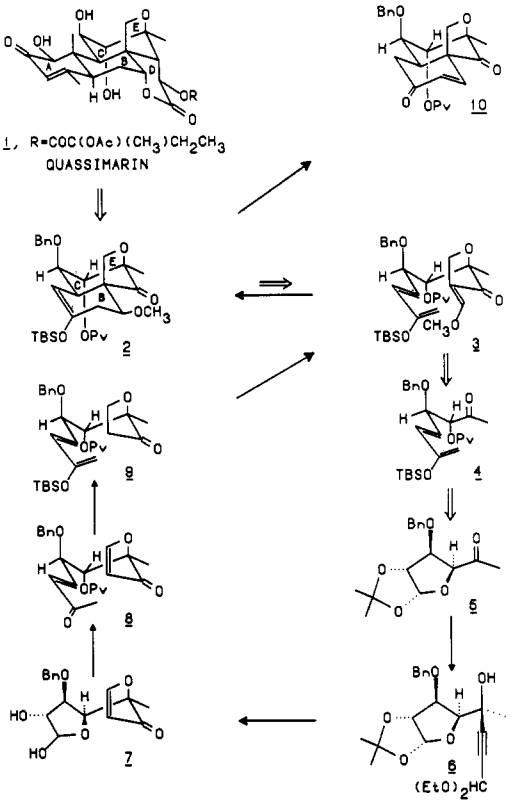
An Approach to Quassimarin Based on an Exo-Selective Intramolecular Diels–Alder Reaction

Summary: A novel exo-selective intramolecular Diels–Alder reaction is used to secure the preparation of the tricyclic adduct **2**, a material that contains three of the rings and five of the stereogenic centers present in the bitter principal quassimarin.

Sir: Quassimarin (**1**)[2] is a pentacyclic bitter principle which has elicited considerable synthetic activity.[3] Certainly, the most beguiling quality of **1** resides in the ring C ensemble, which serves not only as a linchpin for rings B, D, and E but also carries on the remaining nonannulated positions two hydroxyl groups, trans and diaxial to one another.

Our response to the issues presented by ring C led us to recast **1** in terms of the tricyclic species **2**. **2** possesses all but one of the stereogenic centers found on ring C and in addition carries a suitable ring B along with ring E. Via an exo-cyclic retro [4 + 2] cycloaddition,[4] **2** simplifies to the monocycle **3** which we hoped to secure by addition of an appropriate nucleophile to an equivalent of the methyl ketone **4**. The synthesis of **2** together with an X-ray structure of a product derived from **2** are given below.



The methyl ketone **5**[5] served as our synthetic equivalent of **4**. We required for the successful use of **5** in this synthetic scheme a nucleophilic reagent able to undergo Felkin addition onto the methyl ketone and to undergo ready reformulation into a 3-furanone residue. As might be imagined, a number of methods were examined before 1-lithio-3,3-diethoxypropyne[6] (3.1 equiv in Et_2O at −78 °C) was found to react with **5** (1 equiv) in the Felkin mode (17:1)[7] to give **6**, $[\alpha]_D$ −43.11° (*c* 2.35, CH_2Cl_2), in 87%

(1) Hooker Corp. Fellow, Sherman Clarke Fellow, ACS Graduate Fellow in Organic Chemistry.

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(4) Schlessinger, R. H.; Wood, J. L.; Poss. A. J.; Nugent, R. A.; Parsons, W. H. *J. Org. Chem.* **1983**, *48*, 1146.

(5) Kiely, D. E.; Wall, H., Jr.; Black, R. L. *Carbohydr. Res.* **1973**, *31*, 387. Also see, Czernecki, S.; Georgoulis, C.; Provelenghiou, C. *Tetrahedron Lett.* **1976**, 3535. Schmidy, O. T. *Methods Carbohydr. Chem.* **1963**, *2*, 318. Schaffer, R.; Isbell, H. S. *J. Res. Nat. Bur. Stand. (U.S.)* **1956**, *56*, 191.

(6) LeCoq, A.; Gorgues, A. *Org. Synth.* **1980**, *59*, 10.

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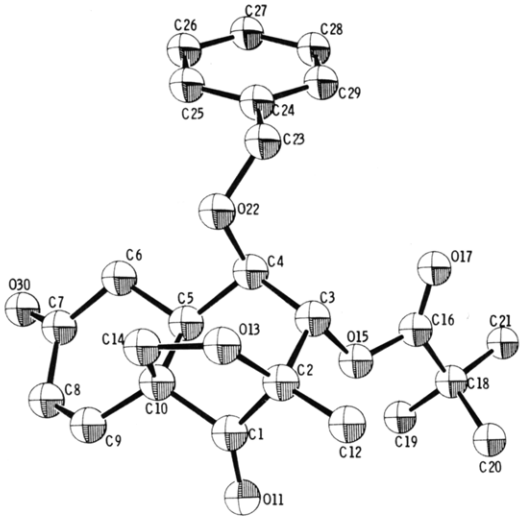

Figure 1.

yield.[8] Admixture of **6** (1 equiv) with 6 N H_2SO_4 (0.1 M in THF at 40 °C for 12 h) both established the furanone ring[9] and removed the acetonide residue to afford **7** in 81% yield (mixture of anomers).

Without purification of intermediates, **7** was converted into the unsaturated ketone **8**. Degradation of the lactol moiety of **7** (1 equiv/0.5 M in THF) into its corresponding β-hydroxy aldehyde was accomplished through the agency of $NaIO_4$ (0.2 M, buffered with $NaHCO_3$, 0.2 M at 0 °C). The latter material (1 equiv, 0.2 M in toluene) was immediately reacted with 1-(triphenylphosphoranylidine)-2-propanone (1.4 equiv at 40 °C for 12 h). Finally, the crude δ-hydroxy-$_{\alpha,\beta}$-unsaturated methyl ketone (1 equiv, 0.2 M in pyridine) was reacted with trimethylacetyl chloride (15 equiv) and 4-DMAP (0.2 equiv) to give **8** $[\alpha]_D$ + 147.15° (*c* 2.00, CH_2Cl_2) in 68% overall yield from **7**.

We now faced the problem of chemically redefining **8** into a species containing diene and dienophilic residues suitable for intramolecular cycloaddition. To this end, we converted the side chain of **8** (1 equiv, 0.2 M in Et_2O) using Et_3N (3.5 equiv) and TBSOTf (1.75 equiv) into its corresponding silyl enol ether diene analogue.[10] This substance (1 equiv, 0.2 M in Et_2O at −78 °C) was then treated with L-Selectride (Aldrich) (1.05 equiv) followed by workup with unsaturated NH_4Cl to afford **9**, $[\alpha]_D$ +29.85° (*c* 1.34, CH_2Cl_2), in 80% overall yield from **8**.[11] Emboldened by the survival of the silyl enol ether residue, we decided to submit it to the reaction guantlet necessary to realize $_{\alpha}$-methylenation of the furanone residue. **9** (1 equiv) dissoleved in HCO_2Et (0.2 M) was treated with NaH (2.5 equiv) and EtOH (0.1 equiv).[12] After workup, the crude reaction product (1.0 equiv in acetone, 0.2 M) was treated with K_2CO_3 (1.3 equiv) and dimethyl sulfate (2.0 equiv) to give **3** as an oil.[13]

The moment of truth in this synthetic scheme was upon us, but out first efforts to achieve intramolecular closure of **3** in an exo-cyclic mode were less than memorable. For example, at 95 °C in toluene, **3** gave a 4:1 mixture of Diels-Alder adducts in low yield. Detailed examination of the ^1H spectrum of these substances did hold some promise in that the spectrum of the major isomer exhibited coupling patterns indicative of the desired exo-cycloaddition adduct **2**.[14] In an effort to enhance both the yield and the selectivity of cycloaddition, we undertook an examination of the influence of Lewis acids on the reaction. Eventually, it was found that treatment of crude **3** (1.0 equiv) in CH_2Cl_2 (0.2 M at −20 °C) with $Al(CH_3)_3$ (1.1 equiv) gave, after standard workup and chromatography, only the exo-adduct **2** as a low-melting solid, $[\alpha]_D$ +80.00° (*c* 2.16, CH_2Cl_2), in 62% overall yield from **9**; 24% overall yield from the methyl ketone **5** (10 steps).

In addition to a detailed spectrscopic analysis of **2**, we further satisfied ourselves of its structure by hydrolysis of the molecule in dioxane containing aqueous H_2SO_4 to obtain the diketone **10** in 70% yield, $[\alpha]_D$ +75.00° (*c* 1.14, CH_2Cl_2). This crystalline substance (mp 127.5–129 °C) was submitted to X-ray analysis which conclusively demonstrated its stereochemistry (Figure 1).[15]

Acknowledgment. We thank L. Symon and C. Poss for help in large-scale preparations of early synthetic intermediates. Financial support from the NIH and the Merck Corp. are gratefully acknowledged.

Supplementary Material Available: X-ray crystal structure data and tables of fractional coordinates and temperature factors, bond lengths, and bond angles (6 pages). Ordering information is given on any current masthead page.

(7) For an excellent discussion of this and related phenomenon, see: Ahn, N.-T. *Top. Curr. Chem.* **1980**, *88*, 145.

(8) The new componds cited in this manuscript gave satisfactory ^1H (300 and 400 MHz) and ^{13}C NMR IR, and mass spectra. Those intermediates that were stable gave correct elemental analyses.

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(11) Ganem, B.; Fortunato, J. M. *J. Org. Chem.* **1975**, *40*, 2846. Ganem, B.; Fortunato, J. M. *Ibid.* **1976**, *41*, 2194.

(12) Trace quantities of ethanol seem to be essential to this reaction.

(13) The geometry of the vinylogous ester **3** is assigned on the basis of work described by: Lubineau, A.; Malleron, A. *Tetrahedron Lett.* **1984**, *25*, 1053.

(14) These coupling patterns were calculated both from molecular models and from MM2 calculations using a program kindly provided us by Professor W. C. Still (Columbia University).

(15) Details available in the form of supplementary material.

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1,2,2,2-Tetrachloroethyl *tert*-Butyl Carbonate: A Simple and Efficient Reagent for the *tert*-Butoxycarbonylation of Amines and Amino Acids

Summary: The reaction of 1-chloroalkyl carbonates with amines affords good yields of the corresponding carbamates. Application to the BOC protection of amino acids is described.

Sir: Since its discovery in 1957,[1] the *tert*-butoxycarbonyl (BOC) group has become the most important amino protecting group in peptide synthesis. Unfortunately, the

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