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2,3-DIHYDRO-3,5-DIHYDROXY-6-METHYL-4H-PYRAN-4-ONE, A NOVEL NONENZYMATIC BROWNING PRODUCT

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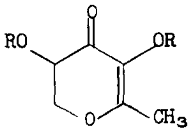
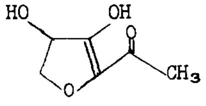
In an extension of our studies on the thermal decomposition of Amadori compounds (1), we have identified 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one (Ia) as the major solid product that is volatilized during the pyrolysis of 1-deoxy-1-(L-prolino)-D-fructose at 138°/1 mm. The structural assignment is significant because it identifies an abundant volatile product formed from a Maillard reaction intermediate, which is highly important in the production of characteristic browned cereal flavors (2), and because it establishes, for the first time, the presence of a dihydropyrone among Maillard reaction products. Also, this assignment replaces structural proposals II and III for a compound that has been isolated from the reaction of D-glucose with methylamine and acetic acid (3), from both acidic and basic degradations of D-fructose (4,5), and from the nonenzymatic browning products of dehydrated orange juice (6). Thus Ia is likely to be formed in most nonenzymatic browning reactions.

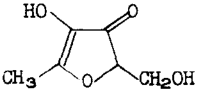


I

a. R = H
b. R = Ac



II



III

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During reinvestigation of the D-fructose degradation product, previously given structure III (4,5,6), Shaw, et al. (7) found it was identical to Severin and Seilmeier's Compound 3 (8) and assigned it structure II (3). Our compound, isolated by GLC from the low-temperature pyrolysis of 1-deoxy-1-(L-prolino)-D-fructose, gave retention data similar to Shaw's and proved to be identical (GLC, MS, NMR) to Severin and Seilmeier's Compound 3 (8).

The IR spectrum of Ia in $CHCl_3$ showed not only the presence of bonded OH with bands at 3,510 and 3,400 (broad) cm^{-1}, but also the existence of an α,β-enone with substitution in the α-position (1,735 very weak, 1,668, and 1,618 cm^{-1}). Mass spectral analysis of Ia established a molecular ion at 144 and the following fragment ions: m/e(rel.%): 144(20), 115(15), 101(20), 85(2), 73(8), 72(15), 55(20), and 43(100). The absence of fragments at M-31(CH_2OH) and M-18(H_2O) make III an unlikely alternative structure. The fragment at m/e 115 was of particular interest since an M-29 peak had not been observed by us from 3(2H)-furanones that we had previously studied; hence, Ia is indicated. Our 100 MHz, NMR analysis of Ia in $CDCl_3$ (Table I) showed the presence of an isolated methyl group, two hydroxyl protons combined in a broad pattern (removed by deuterium exchange), and an ABC pattern for three coupled protons. Structure I was then assigned from the analysis of the 100 MHz, NMR spectra of Ia and Ib.

TABLE I

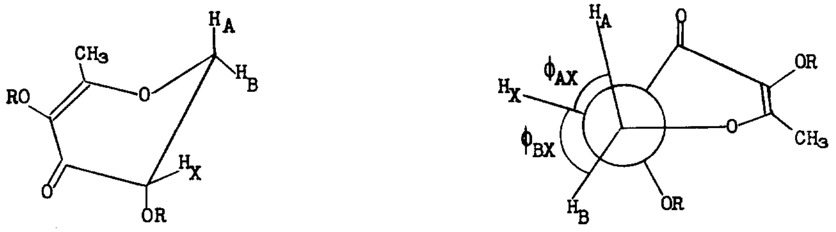
Compound Ia		Compound Ib	
δ(H)*	Assignment	δ(H)*	Assignment
2.05(3,s)**	CH_3-C=C	1.99(3,s)	CH_3-C=C
4.76(2,br)	OH	2.11(3,s)	AcO-C
4.45(1,q)***	H_A J_{AB}, gem = 12 Hz	2.22(3,s)	AcO-C=C
4.34(1,q)***	H_B J_{AC} = 5 Hz, J_{BC} = 14 Hz	4.53(1,q)	H_A J_{AB}, gem = 12 Hz
4.01(1,q)***	H_C	4.39(1,q)	H_B J_{AX} = 6 Hz, J_{BX} = 8 Hz
		5.41(1,q)	H_X

* TMS was used as an internal standard.

** Where s = singlet, br = broad, q = quartet.

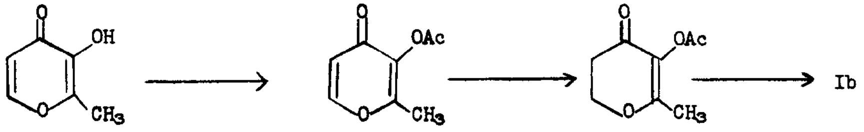
*** δ's were obtained from $CDCl_3$-D_2O solution.

Compounds Ia and Ib possess an uncoupled vinyl-methyl group, which eliminates structure III since ring methyl groups at C5 in similar 3(2*H*)-furanones undergo coupling with the C2 protons (9). As expected, acetylation of Ia shifted the H_C proton downfield (10) to provide an ABX pattern with analyzable characteristics. The near equality of J_{AX} and J_{BX} further support I. The dihydrofuran structure II is not flexible enough to permit H_X to bisect the angle formed by H_A-C-H_B. However, models of the dihydropyrone structure I readily permit a half-chair conformation, IV, in which the dihedral angles, ϕ_{AX} and ϕ_{BX}, and coupling constants, J_{AX} and J_{BX}, would be nearly equivalent. Conformations similar to IV have been proposed for related dihydropyranones of the chromanone system by Crombie, *et al.* (11) and by Katritsky and Ternai (12). The dihedral angles in the other possible half-chair and boat conformations are such that the coupling differences would be much greater than 2 Hz. Hence in retrospect, J_{AC} and J_{BC} indicate the 3- hydroxyl of Ia is pseudo-equatorial.



IV

Structure I was accepted after Ib was synthesized from a pyrone derivative. Maltol (V) was first acetylated and then partially reduced with Pd/C; the resulting dihydro derivative (VI) was acetoxylated (13). The diacetate Ib, isolated in 16% yield from VI, was identical (MS, NMR, IR, and GLC) to the diacetate obtained in Severin and Seilmeier's study and to our acetylated, degradation product.



V VI

Treatment of Ia with methanol-hydrogen chloride at 25° yields isomaltol O-methyl ether (14), a reaction used by Severin and Seilmeier (3) as a proof of structure II. This reaction of Ia is consistent with the expected ease of ring opening of the vinyl ether linkage in the dihydropyrone.

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