methyl to give ethyl β-phenyl-β-hydroxypivalate, the latter on standing in the presence of this base is again decomposed.

4. The mechanisms of the above decompositions are discussed.

DURHAM, NORTH CAROLINA RECEIVED NOVEMBER 9, 1939

[CONTRIBUTION FROM THE UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE]

The Constituents of Certain Species of Helenium. III. The Ester Nature of Tenulin

BY E. P. CLARK

A description of tenulin and some of its derivatives was given in the second paper of this series.[1] No attempt was made to interpret the reactions reported, but as work on the material has progressed facts have emerged that warrant comment.

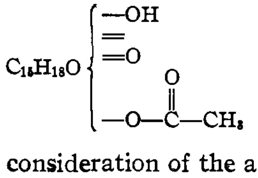
From the data already recorded the following conclusions may be drawn: Tenulin has a double bond, as two atoms of bromine *add* to form a dibromotenulin and hydrogenation with Adams catalyst yields a dihydro compound. Dihydrotenulin, as well as its isomer, dihydroisotenulin, readily forms phenylhydrazones, whereas the unhydrogenated materials do not. It is inferred, therefore, that both tenulin and isotenulin have a carbonyl group, which is sterically hindered by the presence of the double bond. Although tenulin does not give ordinary reactions for hydroxyl groups, the fact that heating it to 300° for a very short time produces an anhydro derivative is a reasonable indication that a sterically hindered hydroxyl group is present.

The work reported at this time shows that tenulin has also another hydroxyl group esterified as an acetate. This information was obtained in experiments having two different lines of approach. First it has been found that alkaline hydrogen peroxide oxidizes both tenulin and isotenulin to a monocarboxylic acid, $C_{15}H_{20}O_7$, which has been named "tenulinic acid." If potassium permanganate is used as the oxidizing agent, another acid, which crystallizes as $C_{17}H_{22}O_8 \cdot {}^1/_2H_2O$, is obtained. The difference between these two acids, aside from the water of crystallization, is C_2H_2O, which should result from the hydrolysis of an acetyl compound. Furthermore, tenulinic acid may be acetylated readily to give a quantitative yield of the second acid, and on hydrolysis it gives back tenulinic acid. The acid obtained by permanganate oxidation of both tenulin and isotenulin is therefore acetyltenulinic acid. The correctness of the formulas of the two acids was checked by the analysis of the acids themselves as well as by the analysis of their methyl esters.

The second approach was to apply hydrolytic reactions to isotenulin. When isotenulin is dissolved in concentrated sulfuric acid and heated for a short time, a substance, $C_{15}H_{20}O_4$, m. p. 255°, is obtained. This has the composition that would result from the hydrolytic loss of an acetyl group from isotenulin. At the same time exactly one mole of acetic acid is formed. The compound $C_{15}H_{20}O_4$, m. p. 255°, is identical with the by-product obtained by the action of 0.1 *N* sodium hydroxide or by prolonged action of 5% sodium carbonate solution on tenulin,[1] and this fact explains its formation as a by-product in the more drastic methods of preparing isotenulin. Further proof that the $C_{15}H_{20}O_4$ compound is deacetylated isotenulin is furnished by its ready reacetylation to isotenulin.

The same hydrolytic action takes place when concentrated sulfuric acid reacts on dihydroisotenulin. The deacetylated product $C_{15}H_{22}O_4$ melts at 203°. Alkali does not have the deep-seated action on dihydroisotenulin that it does on tenulin, and the hydrolysis may be brought about with little loss when aqueous alkali is employed. Both 10 and 50% potassium hydroxide solutions were used, and in each case the desacetyldihydroisotenulin, m. p. 203°, was obtained.

These facts constitute sufficient evidence of the presence of an acetoxy group in tenulin. It thus follows that tenulin may be represented as



$$C_{15}H_{18}O\left\{\begin{array}{l} -OH \\ = \\ =O \\ -O-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3 \end{array}\right.$$

In further consideration of the acetyl group at-

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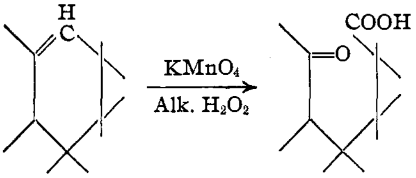
(1) Clark, THIS JOURNAL, 61, 1836 (1939).

tention is directed to the fact that it is more firmly bound than ordinary *o*-acyls. Thus tenulin gave 10.1% acetyl by the standard acetyl method[2] and 12.8% when it was boiled with the alkali reagent for half an hour. The theoretical value is 14.05%. Again the standard procedure for the determination of acetyl in acetyltenulinic acid gave only 3.3% acetyl, and acetyltenulinic acid methyl ester was prepared in good yield by refluxing a solution of the acid in a methanolic hydrochloric acid mixture for one and one-half hours. This phenomenon may be interpreted in several ways, but it seems best to withhold comment until more pertinent facts are accumulated.

Likewise the reaction involving the formation of tenulinic acid is significant aside from the interpretation placed upon it in connection with the ester nature of tenulin. Since neither permanganate nor alkaline hydrogen peroxide attacks desacetyldihyroisotenulin, it is obvious that, in the reaction under consideration, the double bond is involved. The most likely mechanism to account for the addition of three oxygen atoms is the breaking of a double bond in an alicyclic ring to form a ketonic acid. This may be shown schematically as follows

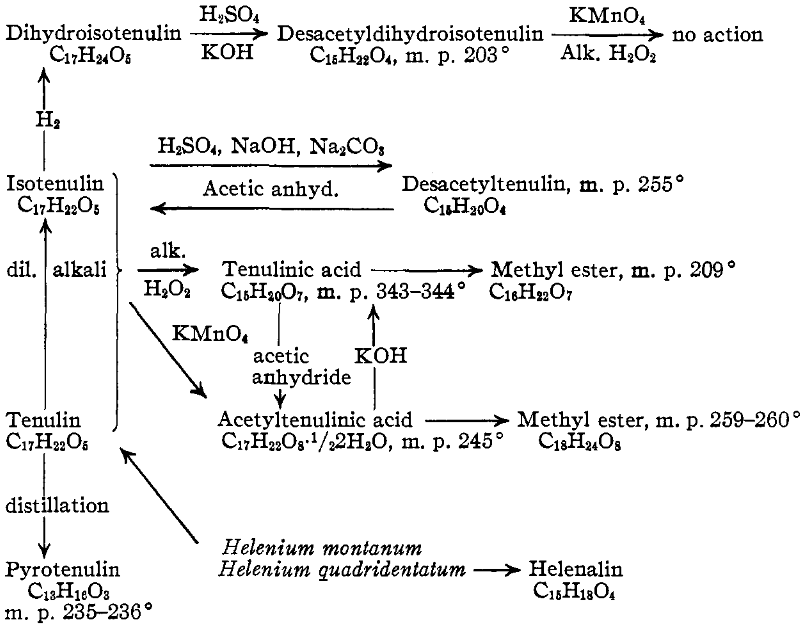


Attempts to prove such a reaction, however, have led to difficulties and further comment is therefore withheld until more information is available.

Another reaction, presented at this time for record only, is that when tenulin is distilled rapidly at atmospheric pressure, it yields a small quantity of a white crystalline compound whose composition is $C_{13}H_{16}O_3$. This has been named "pyrotenulin."

Two hitherto unexamined species of *Helenium*, *H. quadridentatum* and *H. montanum*, also were investigated for bitter and sternutative substances. The procedure followed was the same as that previously used.[1] It was found that *H. quadridentatum* contains helenalin and *H. montanum* yields tenulin.

DIAGRAM SHOWING THE INTERRELATIONS OF PREVIOUSLY UNRECORDED MATERIALS UNDER DISCUSSION



Experimental

Tenulinic Acid.—A solution of 1 g. of tenulin in 10 cc. of acetone, 10 cc. of water, and 8 cc. of 30% hydrogen peroxide was heated to boiling and treated portion-wise with 5 cc. of 10% sodium hydroxide solution. As the reaction and boiling proceeded, 10 cc. of water was added. After all the alkali had been added and the frothing had subsided, the solution was filtered and acidified with sulfuric acid (congo red). Crystallization began at once and yielded 0.57 g. of material which melted at 338–339°. This was recrystallized by acidifying a solution of its sodium salt with sulfuric acid until it had a constant melting point of 343–344°.

The purified product consisted of six-sided rods, many of which were broken into angular fragments. Its refractive indices as determined by the immersion method[3] were η_α, 1.507; η_β, indeterminate; η_γ, 1.595. In parallel polarized light (crossed nicols) the birefringence was extremely strong. Extinction on rods was usually inclined, and the elongation was negative. In convergent polarized light (crossed nicols) no interference figures were observed. The refractive indices were therefore determined by the statistical method. Those rods and fragments showing the maximum double refraction were se-

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(2) Clark, *Ind. Eng. Chem., Anal. Ed.*, 9, 539 (1937).

(3) The optical data recorded in this communication were determined by George L. Keenan, of the Food and Drug Administration of the U. S. Department of Agriculture.

lected for measuring the lowest and the highest indices of refraction.

Anal. Calcd. for $C_{15}H_{20}O_7$: mol. wt., 312.3; C, 57.68; H, 6.46.

Found: mol. wt. (by titration, calcd. to one COOH group), 311; C, 57.65; H, 6.50.

Isotenulin reacted in the same manner as tenulin. The resulting acid was obtained in the same yield as from tenulin, its melting point and composition were identical with those of tenulinic acid, and when the two substances were mixed there was no depression of the melting point.

Anal. C, 57.61; H, 6.63.

Tenulinic Acid Methyl Ester.—This material was made by two procedures. An acetone solution of the acid (0.5 g. in 10 cc.) was treated with an excess of diazomethane. The reaction took place at once, and the resulting solution was evaporated to dryness under reduced pressure. The residue was dissolved in 10 cc. of methanol, and then 30 cc. of water was added. The ester immediately crystallized. It had a m. p. of 208°. Upon recrystallization from methanol–water (1–4), long colorless rods that melted at 209° were obtained.

Anal. Calcd. for $C_{16}H_{22}O_7$: C, 58.88; H, 6.80; OCH_3(1), 9.51. Found: C, 58.94; H, 6.83; OCH_3, 9.55.

The second procedure for preparing the ester consisted in refluxing for one and one-half hours a solution of 0.2 g. of the acid in 5 cc. of methanol and 0.25 cc. of concentrated hydrochloric acid. Upon diluting the reaction mixture with water, long colorless rods were obtained (m. p. 207°). After recrystallization this material did not depress the melting point of the ester made with diazomethane.

Acetylation of Tenulinic Acid.—Tenulinic acid was acetylated by allowing a solution of 0.2 g. of the acid in 2 cc. of pyridine and 1 cc. of acetic anhydride to stand at room temperature overnight. The solution was then diluted with water and acidified with sulfuric acid (congo red). Crystallization began at once, and a quantitative yield of the acetate was obtained. It melted at 243°, and further recrystallizations did not alter the melting point. When mixed with acetyltenulinic acid obtained by permanganate oxidation of tenulin (see below), the melting point was not depressed.

Acetyltenulinic Acid.—A well-stirred solution of 3 g. of tenulin dissolved in 50 cc. of acetone and 25 cc. of water was slowly treated with 330 cc. of 1% aqueous solution of potassium permanganate, and then 3.3 g. of crystalline potassium permanganate was added portionwise. When the reaction was finished, the manganese dioxide was removed by filtration and the filtrate was evaporated, under reduced pressure, to about 60 cc. The concentrate was acidified with sulfuric acid (congo red) and allowed to crystallize. The yield was 1.8 g. of dense colorless crystals, usually joined together in fern-like aggregates. The material melted at 236°. It was recrystallized from its solution in acetone by adding three volumes of water. It then melted at 245°, with the evolution of gas. When it was recrystallized from other liquids its melting point varied from 234 to 245° depending upon the solvent used. Judged from analysis of the various preparations the material was pure, but slight variations in the water of crystallization influenced the melting points. Material crystallized from glacial acetic acid melted at 234–235°. It consisted of sphenoids belonging to the tetragonal system. Many of them broke into irregular fragments. Their refractive indices as determined by the immersion method were as follows: η_ω, 1.544; η_ϵ, 1.552; both ±0.002. In parallel polarized light (crossed nicols) the fragments invariably extinguished sharply, and birefringence was weak. In convergent polarized light (crossed nicols) no interference figures were observed. The refractive indices, therefore, were determined for two positions of extinction on a number of grains in random orientation. One of the values, η_ω, was the same in all grains, while the other of maximum numerical magnitude was designated as η_ϵ.

Anal. Calcd. for $C_{17}H_{22}O_8 \cdot {}^1/_2H_2O$: mol. wt., 363.4; C, 56.19; H, 6.38; acetyl, 11.84. Found: material recrystallized from acetone–water, m. p. 245°; mol. wt. (by titration, calcd. to one COOH group), 363; C, 56.69; H, 6.66; acetyl (standard procedure), 3.3.

As with tenulin, isotenulin also gave acetyltenulinic acid. The identity of the material thus obtained was established by its melting point, mixed melting point and analysis.

Anal. C, 56.53; H, 6.74.

Hydrolysis of Acetyltenulinic Acid.—A solution of 0.1 g. of acetyltenulinic acid in 5 cc. of 10% sodium hydroxide solution was boiled for fifteen minutes. The reaction mixture was then made acid with sulfuric acid (congo red) and allowed to crystallize. This material, after two recrystallizations, melted with decomposition at 343–344°, and there was no depression of the melting point when it was mixed with an authentic sample of tenulinic acid.

Acetyltenulinic Acid Methyl Ester.—This compound was prepared by the two methods used to obtain tenulinic acid methyl ester except that it was crystallized from acetone by adding three volumes of water. When recrystallized to a constant melting point of 259–260°, preparations obtained in both ways consisted of thick plates and prisms.

Anal. Calcd. for $C_{18}H_{24}O_8$: C, 58.69; H, 6.57; OCH_3, 8.42. Found: C, 58.95; H, 6.58; OCH_3, 8.48.

Desacetylisotenulin.—A solution of 1 g. of isotenulin in 4 cc. of concentrated sulfuric acid was heated for one minute in a water-bath at 90°. Crushed ice and water were then added to dilute the mixture to about 50 cc. In a short time crystallization began, and on completion 0.3 g. of white crystals, m. p. 175–183°, was obtained. This product was recrystallized from *n*-butanol to a constant melting point of 255°. When mixed with the compound melting at 255° previously obtained as a by-product from the preparation of isotenulin, there was no depression of the melting point.

Anal. Calcd. for $C_{15}H_{20}O_4$: C, 68.16; H, 7.63. Found: C, 68.32; H, 7.78.

The acid mother liquors from the above experiment contained a volatile acid, which was recovered by distillation and estimated and identified by the Dyer procedure.[4]

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(4) Clark and Hillig, *J. Assoc. Official Agr. Chem.*, **21**, 684 (1938).

The distillation curve for the recovered acid was a straight line with a distillation constant characteristic of acetic acid. The acid was therefore acetic, and the quantity recovered corresponded to one mole of acid from a mole of isotenulin.

Acetylation of Desacetylisotenulin.—A solution of 0.1 g. of the $C_{15}H_{20}O_4$ compound in 1 cc. of pyridine and 0.5 cc. of acetic anhydride was allowed to react overnight. Water was then added, causing the liquid to crystallize. Long colorless rods that melted at 160° were obtained. Recrystallization of these from methanol and water (1–3) raised their melting point to 161°. The product was identified as isotenulin by its melting point, mixed melting point with an authentic sample of isotenulin, and its optical crystallographic properties.

Hydrolysis of Dihydroisotenulin.—Dihydroisotenulin was hydrolyzed with concentrated sulfuric acid by the procedure used with isotenulin. Several days were required for complete crystallization from the reaction mixture. The product was purified by recrystallization from its methanol solution by adding water. It melted at 203°.

Anal. Calcd. for $C_{15}H_{22}O_4$: C, 67.64; H, 8.33. Found: C, 67.88; H, 8.61.

Sodium hydroxide was also used as a hydrolyzing agent. A mixture of 0.5 g. of dihydroisotenulin and 10 cc. of 10% sodium hydroxide was heated and stirred until a homogeneous solution resulted. This was then diluted with water to *ca.* 50 cc. and acidified to congo red with sulfuric acid. Colorless crystals (240 mg.) separated. They melted at 202°, and when they were mixed with the compound obtained above with sulfuric acid there was no depression of the melting point. The acid mother liquors were examined for acetic acid as reported under isotenulin. The results were identical.

Pyrotenulin.—A half gram of purified tenulin was heated until the first violent evolution of gas ceased. The resulting melt was then placed in a strong Bunsen flame and rapidly distilled. The distillate was caught in a thin-walled bulb blown close to the bottom of the test-tube. This was broken, and its contents dissolved in chloroform. The solution was filtered through Norit and diluted with several volumes of methanol. The liquid was distilled until the chloroform was removed, whereupon the methanol concentrate crystallized. The product consisted of colorless hexagonal plates, m. p. 235–236°.

Anal. Calcd. for $C_{13}H_{16}O_3$: C, 70.88; H, 7.32. Found: C, 70.90; H, 7.22.

Summary

Evidence has been presented to show that tenulin contains a double bond, an acetoxyl group, and a hydroxyl and a carbonyl group, both of which are sterically hindered.

A summary of the reactions of tenulin which have been used in this discussion and which have hitherto been unrecorded is shown diagrammatically in a chart.

Two hitherto unexamined species of *Helenium*, *i. e.*, *H. quadridentatum* and *H. montanum*, have been investigated for bitter and sternutative substances. *H. quadridentatum* contains helenalin, while *H. montanum* contains tenulin.

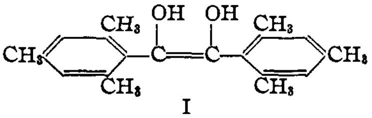
WASHINGTON, D. C. RECEIVED JANUARY 4, 1940

[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

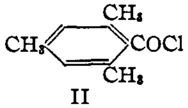
Enediols. III. 1,2-Dimesitylacetylene Glycol

BY REYNOLD C. FUSON, C. H. MCKEEVER[1] AND JOSEPH CORSE

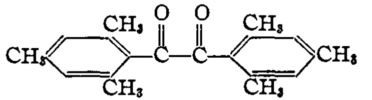
The isolation of a stable enediol, 1,2-dimesitylacetylene glycol (I), was reported recently.[2] The present paper presents the experimental details upon which the earlier communication was based. The enediol was obtained by the action of the binary mixture, $Mg + MgI_2$,[3] on mesitoyl chloride (II) or mesitil (III). The products from the two sources were identical. Both reverted to the benzil when exposed to the air or other oxidizing agents, and both rearranged to mesitoin (IV) under the influence of hydrochloric acid.



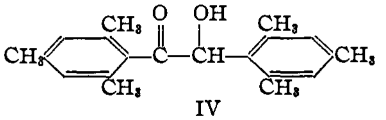
I



II



III



IV

Treatment of this enediol with acetic anhydride gave a diacetate (m. p. 164–165°) accompanied by a very small amount of a second diacetate (m. p. 218°). Mesitil and the acetate of mesitoin were also isolated.

Benzoylation with benzoyl chloride in the presence of pyridine converted the enediol into a dibenzoate melting at 188.5–189.5°.

By hydrogenation of mesitil in methanol,

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[1] Röhm and Haas Research Assistant.

[2] Fuson and Corse, THIS JOURNAL, **61**, 975 (1939).

[3] Gomberg and Bachmann, *ibid.*, **49**, 236 (1927).