Anal. Calcd. for $C_{12}H_6O_3NAsCl_2$: As, 20.95; Cl, 19.83. Found: As, 21.05, 21.04; Cl, 19.57, 19.61.

Structure Proof.—An intimate mixture of 15 g. of 8-nitro-3-dibenzofuryldichloroarsine and 15 g. of mercuric acetate was fused for ten minutes at 350°. An acetic acid extract of this melt on dilution with water gave 1 g. of a yellow solid, m. p. 149° after crystallization from an alcohol-acetone mixture. It was identified as 2-nitrodibenzofuran by means of a mixed melting point.[9] Reduction of this compound gave 2-aminodibenzofuran, m. p. 125°, and acetylation of the amine produced 2-acetaminodibenzofuran, m. p. 162°.

8-Nitro-3-dibenzofurylarsine Oxide.—A quantitative yield of the oxide was obtained by the hydrolysis of 2 g. of 8-nitro-3-dibenzofuryldichloroarsine with boiling water for four hours; light orange product after crystallization from methyl cellosolve, not melted at 250°.

Anal. Calcd. for $C_{12}H_4O_4NAs$: As, 24.75. Found: 24.67, 24.65.

8-Amino-3-dibenzofurylarsonic Acid.—A quantitative yield of this acid was obtained by reducing an alkaline solution of 8-nitro-3-dibenzofurylarsonic acid with hydrogen using the Raney catalyst.[10] Acidification to litmus with concd. hydrochloric acid produced a white precipitate of the amine which was recrystallized from dilute hydrochloric acid; not melted at 250°.

Anal. Calcd. for $C_{12}H_{10}O_4NAs$: As, 24.43. Found: As, 24.48, 24.44.

Sulfo-3-dibenzofurylarsonic Acid.—A suspension of 9 g. of 3-dibenzofurylarsonic acid in 60 cc. of concd. sulfuric acid was heated over a steam-bath for two hours. The solution was then cooled in an ice-bath and diluted with water until a heavy white precipitate was formed; not melted at 300° after recrystallization from water. The structure of this compound has not been proved but it is probably 8-sulfo-3-dibenzofurylarsonic acid.

Anal. Calcd. for $C_{12}H_9O_7SAs$: As, 20.16. Found: As, 20.30, 20.27.

Sulfo-3-dibenzofurylarsine Oxide.—An 80% yield of the oxide was obtained by bubbling sulfur dioxide through a solution of 0.5 g. of potassium iodide, and 1 g. of sulfo-3-dibenzofurylarsonic acid in 150 cc. of 2 *N* hydrochloric acid. At the end of twenty minutes the precipitated arsine oxide was filtered out and purified by salting it out of a water solution, not melted at 275°.

Anal. Calcd. for $C_{12}H_7O_6SAs$: As, 22.19. Found: As, 22.39, 22.37.

(10) Raney, U. S. Patent 1,628,190 (1927).

Summary

1. Direct arsonation of dibenzofuran gives 2-dibenzofurylarsonic acid as shown by structure proof; its oxide is described.

2. 3-Dibenzofurylarsonic acid has been prepared through the diazo reaction and converted into the dichloroarsine and oxide by reduction. Nitration of 3-dibenzofurylarsonic acid gives the 8-nitro derivative and from this the corresponding amine compound has been obtained by catalytic reduction.

3. 3-Dibenzofurylarsonic acid has been sulfonated directly.

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[CONTRIBUTION FROM THE BIOCHEMICAL LABORATORY, STATE UNIVERSITY OF IOWA, AND THE INSTITUTE OF EXPERIMENTAL BIOLOGY, UNIVERSITY OF CALIFORNIA]

Antioxidants and the Autoxidation of Fats. IX. The Antioxidant Properties of the Tocopherols

BY H. S. OLCOTT AND O. H. EMERSON

The unsaponifiable fraction of some vegetable oils exhibits marked antioxidant properties when small amounts are added to lard. Olcott and Mattill[1] have recorded some of the characteristics of the active principles which they called inhibitols. When wheat germ oil or cottonseed oil was used as the source, the inhibitol concentrates contained a large amount of vitamin E from which the inhibitols could not be separated. The successful isolation of three individual compounds possessing vitamin E activity from these oils by Evans, Emerson and Emerson[2-4] provided an opportunity for ascertaining the relationship between the inhibitols and tocopherols.

The three tocopherols and their allophanates were assayed for antioxidant activity by the oxygen absorption method previously described.[5] The tocopherols were effective antioxidants in lard and oleo oil, but had no activity in esters prepared from hydrogenated cottonseed oil (Table I). Since the inhibitol concentrates from wheat germ oil and cottonseed oil behave similarly,[6] it seems apparent that they owe at least part, and possibly all, of their antioxidant activity to the tocopherols. However, the inhibitols obtained

(1) Olcott and Mattill, THIS JOURNAL, **58**, 1627 (1936).
(2) Evans, Emerson and Emerson, *J. Biol. Chem.*, **113**, 319 (1936).
(3) Emerson, Emerson and Evans, *Science*, **83**, 421 (1936).
(4) Emerson, Emerson, Mohammed and Evans, in press.
(5) French, Olcott and Mattill, *Ind. Eng. Chem.*, **27**, 724 (1935).
(6) Olcott and Mattill, THIS JOURNAL, **58**, 2204 (1936).

from lettuce[7] and tomatoes[8] in the methanol fraction after distribution between petroleum ether and 92% methanol are presumably not tocopherols, since the latter, on distribution between these solvents, are found in the petroleum ether phase, and have, moreover, appreciably higher boiling points.

TABLE I

ANTIOXIDANT PROPERTIES OF THE TOCOPHEROLS AND THEIR ALLOPHANATES

Added antioxidant	% used	Induction period at 75° Exptl.	Control
Substrate fat: Lard			
α-Tocopherol[a]	0.01	36	13
	.01	20	15
	.02	60	15
	.02	74	13
	.02	62	15
β-Tocopherol	.01	61	14
	.02	96	14
	.02	99	15
γ-Tocopherol[b]	.01	96	10
	.01	107	11
	.02	150	10
	.02	166	11
α-Tocopherol allophanate[c]	.02	85	20
	.02	114	17
β-Tocopherol allophanate[d]	.02	132	20
	.02	166	17
γ-Tocopherol allophanate[e]	.02	156	20
	.02	172	17
Oleo oil			
α-Tocopherol	.01	32	12
γ-Tocopherol	.01	110	12
	.02	360	12
Crude esters hydrogenated cottonseed oil			
α-Tocopherol	0.01	2.5	2.5
	.02	2.0	2.0

[a] Approximate minimum effective dose when administered to vitamin E deficient female rats; α-tocopherol, 1–3 mg.; β-tocopherol, 3–5 mg.; γ-tocopherol, 1–3 mg. Biological assays from the two laboratories showed reasonable agreement. [b] The γ-tocopherol and its allophanate used in these tests contained some α-tocopherol. [c] M. p. 157–158°. [d] M. p. 138°. [e] M. p. 135–135.5°.

The tocopherols are increasingly effective as antioxidants in the order α, β, γ. On the other hand, as vitamin E, β is less effective than α or γ. This lack of correlation between the antioxidant and vitamin properties of the pure substances offers an explanation for the previously observed lack of direct relationship in the concentrates.[1,6]

Vitamin E concentrates virtually free from antioxidant activity have been described.[7,8] A possible explanation of these results may be based on the assumption that the preparations were not completely hydrolyzed. Simple esters of the tocopherols are effective as the vitamin, but ineffective as antioxidants. The possibility that vitamin E may occur in nature in the form of an ester has been suggested previously.[9]

The antioxidant activity of the tocopherol allophanates (Table I) was unexpected, inasmuch as previous observations had indicated that the activity of inhibitols and of antioxidants of known structure depended on the presence of a free hydroxyl group.[1,10] However, the fact that α-naphthol allophanate[11] is also an effective antioxidant while cholesterol allophanate is not, suggests that the activity of the allophanates parallels that of the parent compounds.

Since antioxidants of known structure are phenolic in nature,[10] the antioxygenic activity of the tocopherols suggests that they may belong to this class of substances. The absorption spectrum of the tocopherols resembles that of hydroquinone; however, the tocopherols differ from most phenols in having little or no acidic properties.

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Summary

α, β and γ tocopherols and their allophanates are effective antioxidants in lard. The degree of protection afforded by the tocopherols is not proportional to their vitamin E activity.

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(7) Olcott and Mattill, *J. Biol. Chem.*, **93**, 59, 65 (1931).
(8) Bradway and Mattill, THIS JOURNAL, **56**, 2405 (1934).
(9) Olcott, *J. Biol. Chem.*, **110**, 695 (1935).
(10) Olcott, THIS JOURNAL, **56**, 2492 (1934).
(11) The preparation and properties of this compound will be described in another place.