functional groups did not react under the phosphorylation conditions used, except in the case of oleyl alcohol. This was confirmed by functional group analyses and infrared spectra. In the case of oleyl alcohol, in addition to reaction of the double bond, the terminal group also reacted to form a dialkylphosphite. To confirm the general course of this reaction, the corresponding saturated fatty alcohol, stearyl alcohol was reacted under the general conditions of the phosphorylation reaction. Distearylphosphite was obtained in high yield; acidic hydrolysis yielded the starting fatty alcohol.

Considerable work is in progress to extend the scope of this reaction to other fatty unsaturated materials, as well as to additional olefinic structures. Related phosphorylating agents, such as phenylphosphorus dichloride, are also being studied. The chemistry of the reaction is quite complex and further basic studies are required. In addition, there exists a tremendous potential for doing creative application research.

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Nitration of Methyl Oleate with Acetyl Nitrate: A Synthesis of Methyl Aminostearate[1]

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Abstract

Acetyl nitrate, an effective reagent for the nitration of simple alkenes, provided a convenient means of introducing nitrogen into unsaturated fatty acids. This nitrating agent was found to react quantitatively under mild conditions with methyl oleate forming isomeric nitro, acetoxy-nitro, and nitro-nitrate derivatives. These nitro derivatives were isolated by column and thin-layer adsorption chromatography, and their structures were elucidated by infrared spectroscopy.

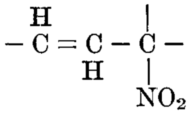
In addition, the isomeric nitro derivative was reduced by catalytic hydrogenation to give methyl aminostearate.

Introduction

IN THE PREPARATION of fatty nitrogen derivatives, nitrogen is usually introduced into the fatty acid molecule by reactions of the carboxyl group with ammonia or amines. Such reactions yield high-molecular-weight nitriles and amides that are convenient intermediates for preparing amino and quaternary ammonium compounds.

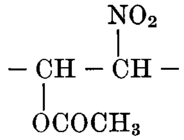
Relatively few methods have been described for introducing nitrogen into the fatty acid chain at the sites of unsaturation. Nevertheless, reactions of this type may be expected to yield derivatives that have useful and interesting properties. Fatty acid derivatives containing nitrogen are important industrially as surfactants, germicides, and fungicides (1).

The present communication reports that acetyl nitrate, an effective reagent for nitrating simple alkenes (2), reacts quantitatively with methyl oleate forming isomeric nitro (I), acetoxy-nitro (II), and nitro-nitrate (III) derivatives.



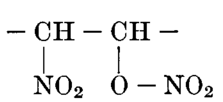
$$-\overset{H}{C}=\underset{H}{C}-\underset{NO_2}{\overset{|}{\underset{|}{C}}}-$$

I



$$-\underset{OCOCH_3}{CH}-\overset{NO_2}{CH}-$$

II



$$-\underset{NO_2}{CH}-\underset{O-NO_2}{CH}-$$

III

These derivatives were isolated from the nitration mixture by column and thin-layer chromatography (TLC), and their structures were elucidated by infrared spectroscopy. Structures of isomers of derivative I were determined *via* oxidative degradation of the double bonds. In addition, methyl aminostearate was synthesized from derivative I by catalytic hydrogenation.

Experimental

Nitro Derivatives: Analysis and Structure

Nitration of Methyl Oleate. The reaction of acetyl nitrate with methyl oleate (obtained from the Hormel Foundation, Austin, Minn.) was conducted as follows: 5 ml (0.08 mole) of colorless 70% nitric acid was added slowly to 70 ml of acetic anhydride at 15C. The temperature of the reaction was maintained between 20 and 25C by controlling the rate of addition of nitric acid. Methyl oleate (3.6 g, 0.012 mole) was added to the acetyl nitrate solution, and the reaction was continued at about 25C for 1 hr. The reaction was terminated by adding 150 ml of ice water, and the products were extracted from the resulting mixture with diethyl ether. The extract was washed with distilled water until the washings were neutral and then was dried over anhydrous Na_2SO_4. The product (3.7 g) was recovered after evaporation of the solvent.

Analysis and Isolation of Nitro Derivatives by TLC. The product from the nitration of methyl oleate was resolved into its components by TLC on silicic acid (4) using 85:15 petroleum ether-diethyl ether as the eluent. Individual spots were charred with 50% H_2SO_4 and then analyzed with a densitometer as previously described (5). Small amounts (50–100 mg) of derivatives I, II, and III were obtained by chromatography on 1 mm layers of silicic acid using 85:15 petroleum ether-diethyl ether as the eluent. The purity of each fraction eluted from the silicic acid was confirmed by analytical TLC (4). The identity of each fraction was verified by infrared analysis. The presence of the acetoxy group in II was established by the infrared absorbance characteristic of hydroxyl groups in the corresponding nitro alcohol derivative (2). Characteristic infrared absorbancies of the derivatives were as follows: I, 6.43 μ (unconjugated

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[1] Presented at the AOCS meeting in Toronto, Canada, 1962.

[2] Division of Industrial Research, Fish and Wildlife Service, U. S. Department of the Interior.

TABLE I
Nitro Derivatives Formed in Nitration of Methyl Oleate

Derivatives	Composition, %
Isomeric-nitro (I)	28
Acetoxy-nitro (II)	41
Nitro-nitrate (III)	23
Unknown	5

nitro group) and 10.33 μ (isolated *trans* bonds); II, 6.43 μ and 3.1 μ (OH absorbance of nitro-alcohol derivative); III, 6.45 μ (nitro group), and 6.12 μ, 7.90 μ, and 11.65 μ (nitrate group) (3). The composition of the nitrated methyl oleate is shown in Table I.

Isolation of Isomeric Nitro Derivatives by Column Chromatography. Chromatography of 721 mg of the nitrated methyl oleate on a column of silicic acid (Mallinckrodt, chromatographic grade), using 95:5 petroleum ether(bp 30–60C)-diethyl ether as eluent, yielded 163 mg (23%) of isomeric nitro compounds. Infrared analyses of these compounds showed strong absorbancies that were attributed to unconjugated nitro groups and isolated *trans* bonds. The relative absorption due to *trans* unsaturation was approximately equal in magnitude to that of pure methyl elaidate. Analytical TLC of 1 mg of the isomers on silicic acid, using 95:5 petroleum ether-diethyl ether as eluent, showed the fraction to be composed only of isomers of a single class.

Analysis: Calculated for $C_{19}H_{35}NO_4$: C, 66.83; H, 10.33; N, 4.10. Found: C, 67.74; H, 10.07; N, 3.94.

Structures of Isomeric Nitro Derivatives. Oxidation of 50 mg of the isomeric nitro derivatives with $KMnO_4/CH_3COOH$ for 5 hr at 25C (6) yielded nitro-substituted and unsubstituted mono- and dicarboxylic acids. The unsubstituted acids, which were equivalent to specific isomers in the fraction of nitro derivatives isolated by column chromatography, were analyzed by gas-liquid chromatography as methyl esters. The nitro-substituted methyl esters, which bound strongly to the column, did not interfere with determination of the unsubstituted derivatives. Analyses were carried out with a Research Specialties Instrument (model 600) equipped with a 7 ft × ¼ in. aluminum column packed with 5% diethylene glycol succinate polymer (DEGS) on siliconized (7) Chromosorb W (110–120 mesh). The flow rate was 20 ml of argon per minute. The temperature was increased linearly from 120–165C during chromatography so that both mono- and dicarboxylic acid esters could be conveniently separated in a short time on the same column. Two monocarboxylic acid esters (methyl octanoate and methyl nonanoate) and two dicarboxylic acid esters (dimethyl octanedioate and dimethyl nonanedioate) were identified and determined quantitatively by use of standards. Based upon the above analyses, derivative I, obtained by column chromatography, was found to be composed of 4 isomers (Table II).

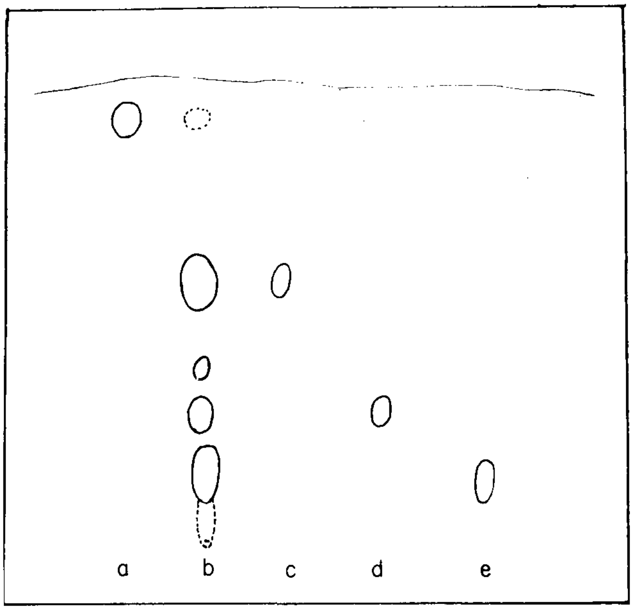

FIG. 1. Silicic acid chromatogram of fatty acid derivatives; a, methyl oleate; b, crude nitrated methyl oleate; c, isomeric nitro derivative; d, nitro-nitrate derivative; e, acetoxy-nitro derivative. Solvent: 85:15 petroleum ether-diethyl ether. Indicator: 50% sulfuric acid.

TABLE II
Isomeric Methyl Nitro-Octadecenoates Obtained by Column Chromatography

Isomers	Composition, %
Methyl 8-nitro-octadeca-*trans*-9-enoate	16
Methyl 9-nitro-octadeca-*trans*-10-enoate	10
Methyl 10-nitro-octadeca-*trans*-8-enoate	33
Methyl 11-nitro-octadeca-*trans*-9-enoate	41

Methyl Aminostearate: Preparation and Purification

Preparation. Fractions of isomeric nitro derivatives, obtained by column chromatography as previously described, were dissolved in absolute ethanol and converted to amines by hydrogenation over Raney Nickel (W-2) catalyst (8). Reductions were conducted at 4 atm for 20 hr at room temperature in a Parr apparatus.

Flash distillation (150–160C/0.1 mm) of the crude amines (200 mg) yielded 180 mg of a colorless distillate ($n_D^{25} = 1.4508$; % N = 3.71). Infrared analysis of the distillate indicated the absence of nitro groups and of carbon-to-carbon double bonds. A weak absorbance at 3.0 μ was attributed to the presence of amine groups. TLC on silicic acid, using 95:5 petroleum ether-diethyl ether as the eluent, indicated an impurity of 15–20% methyl stearate. The composition of the distillate, calculated from the % N, was found to be about 17% methyl stearate and 83% methyl aminostearate.

Purification. Methyl aminostearate was purified as follows: 1.0 g of impure derivative was converted to the hydrochloride salt under anhydrous conditions with HCl in diethyl ether. The hydrochloride was dissolved in 75 ml of distilled water, and insoluble compounds were removed with successive washings of petroleum ether. The aqueous phase was made slightly basic with 10% KOH and was then washed several times with diethyl ether. The combined diethyl ether washings were dried over anhydrous Na_2SO_4, and the solvent was evaporated. Flash distillation (150–160C/0.1 mm) of the residue yielded 0.35 g of purified methyl aminostearate ($n_D^{25} = 1.4528$).

Analysis: Calculated for $C_{19}H_{39}NO_2$: C, 72.79; H, 12.54; N, 4.47; % NH_2, 5.10; molar refractivity, 95.0. Found: C, 72.41; H, 12.53; N, 4.35; % NH_2,[3] 4.89; molar refractivity, 94.0.

Discussion

TLC demonstrated that methyl oleate was quantitatively nitrated using acetyl nitrate at room temperature for 1 hr. It may be seen from examination of the thin layer chromatogram (Fig. 1) that mixtures of the nitro compounds were easily resolved by adsorption chromatography on silicic acid. A compound of undetermined structure, having slightly greater polarity than the nitro-nitrate derivative,

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[3] Determined by the method of Siggia and Stahl (9).

comprised about 5% of the nitrated methyl oleate.

Some nitro derivatives obtained from nitrations using acetyl nitrate are unstable at elevated temperatures (2). Nitro-acetates derived from styrene, for example, were found to decompose into acetic acid and β-nitro styrene on attempted distillation (10). Although the derivatives described in this paper were also unstable at high temperature, no apparent decomposition occurred under normal handling conditions.

The principal impurity formed in reduction of the isomeric nitro derivatives was methyl stearate, thus indicating that hydrogenolysis was the predominant side-reaction. Methyl aminostearate was a colorless, odorless liquid, and unlike the nitro intermediates, appeared to be stable during distillation.

Unsaturated fatty acids have been nitrated previously with N_2O_4 and other nitric acid derivatives (11,12,13). Usually, these reagents are corrosive, hard to handle, and may lead to formation of large varieties of products that are difficult to resolve. In the present work, use of acetyl nitrate at room temperature has enabled us to nitrate methyl oleate without encountering these difficulties. This reagent is also being used for nitrating methyl linoleate, methyl linolenate, and fractions of methyl esters derived from menhaden oil (14). In these nitrations, nitro, acetoxy-nitro, and nitro-nitrato groups were introduced into the fatty acid chains using conditions similar to those described here.

In conclusion, acetyl nitrate is a convenient and effective reagent for nitrating a variety of unsaturated fatty acid derivatives. Compounds obtained from these nitrations are potentially useful intermediates for synthesizing derivatives having groups centrally located in the molecule such as amines, amino-acetates, and amino-alcohols.

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Hydrogenation of Linolenate. VII. Separation and Identification of Isomeric Dienes and Monoenes[1]

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Abstract

Isomeric dienes and monoenes produced by partial hydrogenation of linolenic acid have been separated by the combined use of low-temp crystallization and countercurrent distribution. *Cis,trans* dienes have been separated from *cis,cis* dienes. *Cis,cis* conjugatable dienes have been partially separated from *cis,cis* nonconjugatable dienes. Dienes with one *trans* double bond were separated by gas chromatography into two groups: *cis,trans* and *trans,cis*. Individual positional isomers could not be separated.

Cis-9 monoene was separated from *cis*-12, *cis*-15, and *trans* monoenes by low-temp crystallization. Countercurrent distribution at 3,000 transfers only partially separated this mixture of *cis*-12, *cis*-15, and *trans* monoenes. The double bond in both *cis* and *trans* monoenes was found in all carbon positions, 7 through 16, showing for the first time that the 15,16 bond of linolenic acid had moved away from the carboxyl. The major *cis* bonds remained at carbons 9, 12, and 15.

Combination of countercurrent distribution fractions has produced samples containing 95% *cis,cis* dienes; 90% *cis,trans* or *trans,cis* dienes; 95% *cis* monoenes; and 90% *trans* monoenes.

Introduction

RESEARCH of the last decade on the hydrogenation of unsaturated fatty acids or their esters has stressed the formation of geometric and positional isomers (1–7). Highly unsaturated acids, such as linoleic and eleostearic, have been reduced to monoenes, and the mixture has been analyzed for both types of isomers. Allen (3) reported the separation of *cis* from *trans* monoenes but experimental details were not given. Lemon (8) hydrogenated linseed oil until no alkali isomerizable acids were present and isolated an "isolinoleic" acid having at least one double bond in *trans* configuration. Rabello and Daubert (9) hydrogenated linolenic acid to a similar degree and isolated (by low-temp crystallization) an "isolinoleic" acid concentrate composed of at least three positional isomeric dienes. This concentrate included only a part of the dienes formed since a majority was lost in the fractionation procedure.

Rebello and Daubert (9) have pointed out that 15 positionally isomeric dienes could be formed from linoleic acid on reduction of one of its double bonds if one assumes the migration of residual bonds by one carbon atom to either side of the original position. Geometric isomers containing either one or two *trans* bonds can also be formed so the total number of possible isomeric dienes in partly reduced linolenic acid becomes staggering.

The first paper in this series (10) showed that dienes formed by partial catalytic hydrogenation of

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