# A Convenient Method for the Preparation of Pheromones from Inexpensive Starting Materials

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Pheromones, (*Z*)-9-Tetradecenoic Acid, (*Z*)-9-Tetradecenol, (*Z*)-9-Tetradecenyl Acetate, (*Z*)-9-Tetradecenal

(*Z*)-9-Tetradecenoic acid was isolated from the total fatty acids of beef tallow. (*Z*)-9-Tetradecenol, (*Z*)-9-tetradecenyl acetate and (*Z*)-9-tetradecenal, compounds known to function as sex attractants in various insect species, were prepared from this fatty acid.

## Introduction

Many aliphatic compounds having 12, 14, or 16 carbon atoms and one or two double bonds are known to function as "chemical messengers" between different sexes of the same insect species [1]. Saturation of a mating area with high concentrations of such a "pheromone" may be used to inhibit olfactory orientation between sexes. Moreover, by using sex attractant pheromones, certain insects may be drawn into traps. Hence, pheromones can be used for the biological control of insect pests [1].

The preparation of sex attractants by chemical synthesis is tedious, mainly because of the difficulties encountered in separating the mixtures of (*Z*)- and (*E*)-isomers formed. (*Z*)-9-Tetradecenol, for example, the sex pheromone of the fall army worm (*Laphygma frugiperda*) can be obtained together with the (*E*)-isomer by a Wittig synthesis; the desired (*Z*)-9-tetradecenol must be isolated by chromatography [2].

We have found beef tallow and fats from slaughtering wastes to be excellent raw materials for the isolation of (*Z*)-9-tetradecenoic acid. The aim of the present work was the isolation of this acid in high purity, and the preparation of the corresponding alcohol, alkyl acetate and aldehyde, derivatives, which can serve as pheromones for the control of a variety of insects.

In view of the abundance and the low cost of the starting material, the process described can be considered economical, although the yield of the desired fatty acid is fairly low.

## Experimental

### *Analytical methods*

The course of reactions and the purity of products were followed by thin-layer chromatography on Silica Gel G using mixtures of hexane with diethyl ether as solvents; lipid fractions were detected by charring after spraying the plates with chromic – sulfuric acid solution.

Mixtures of fatty acids were esterified with methanol using conc. sulfuric acid as catalyst, and the resulting methyl esters were analyzed by gas chromatography on a Perkin-Elmer F7 Fractometer equipped with flame ionisation detector and a column, 10 ft × ⅛″, packed with 10% EGSS-X on Gas-Chrom P, 100–120 mesh; the temperature of the injection port was 260 °C whereas the column temperature was 175 °C.

The location of the double bond in the tetradecenoic acid isolated was determined by reductive ozonolysis [3] of 0.1 mg of methyl tetradecenoate followed by analysis of the products formed. The ozonolysis products of authentic methyl (*Z*)-9-hexadecenoate and methyl (*Z*)-9-octadecenoate were analyzed for comparison. Gas chromatography of the ozonolysis products was carried out with the instrument and the column used in the analysis of methyl esters. The temperature of the injection port was 210 °C, that of the column was programmed from 45 to 180 °C at a rate of 5 °C per minute.

In the gas chromatography of methyl esters as well as their ozonolysis products the flow rates of hydrogen and nitrogen were adjusted to yield optimum

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resolutions. Peak areas were determined by triangulation.

Infrared spectra were taken on a Leitz Infrared Spectrograph using carbon tetrachloride as solvent.

Melting points and critical solution temperatures with nitromethane were determined on a Kofler heating stage under the microscope.

*Isolation of tetradecenoic acid*

The starting material, a mixture of fatty acids that had been obtained by the saponification of beef tallow followed by two consecutive distillations, was kindly provided by Dr. W. Stein, Henkel and Cie GmbH, D-4000 Düsseldorf, Germany. The distillation of 750 kg of total fatty acids, that contained 0.2% of tetradecenoic acid, has yielded 107 kg of a mixture that contained 3.5% of the desired acid. Fractional distillation of this forerun afforded 34.5 kg of fractions 1–10 with a content of 0–5.5%, and 60.3 kg of fractions 11–27 with a content of 10.3–15.9% of tetradecenoic acid; the residue, 7.0 kg, contained 4.5% of this acid.

Tetradecenoic acid was enriched further from a mixture of about 25 kg of fatty acids that contained 10.3% of this acid. A solution of the mixture in acetone, 10%, w/v, was cooled to −36 °C, and the supernatant solution, which contained a mixture of fatty acids with 28.6% of tetradecenoic acid was collected by centrifugation. Part of the acetone was distilled off to yield a 30% solution which was cooled to −36 °C. After centrifugation, 2.2 kg of a mixture of fatty acids with 50.5% tetradecenoic acid was obtained from the supernatant. The fatty acids were converted to methyl esters and these were subjected to fractional distillation at 12 mm using a packed 'Normag' column, 150×3 cm (i.d.). A total of 1.5 kg of methyl esters of fatty acids with 14 carbon atoms was obtained in fractions that contained from 65 to 80% of methyl tetradecenoate. Cooling of these methyl esters to −36 °C followed by centrifugation yielded 0.8 kg of a concentrate with a content of 90% methyl tetradecenoate.

Pure methyl tetradecenoate was isolated from this concentrate by argentation chromatography on a column, 3×20 cm, of Florisil, 60–200 mesh, impregnated with 20% silver nitrate using mixtures of hexane-diethyl ether, 90:5 to 60:40, as developing solvents. Aliquots of 5 g concentrate yielded 4.2 g of pure methyl tetradecenoate. A total of 42 g of the pure methyl ester was prepared; m.p. −26 to −23 °C, $CST_{(MeNO_2)}$ −3 °C.

*Preparation of pheromones*

Following an established procedure [4], *tetradecenol* was prepared from the concentrate (a) and from pure (b) methyl tetradecenoate.

(a) An aliquot of the concentrate of methyl tetradecenoate, 140 g (0.6 mol), dissolved in 500 ml of anhydr. diethyl ether, was added dropwise to a solution of 38 g (1.0 mol) of lithiumaluminumhydride in 1 l of anhydr. diethyl ether. The reaction mixture was heated to reflux under magnetic stirring for 4.5 h, excess reagent was destroyed by the addition of dilute hydrochloric acid, and the etheral solution was washed consecutively with several portions of dilute sodium carbonate solution and water until neutral. After drying of the solution over anhydr. sodium sulfate and evaporation of the solvent, 118.7 g (95% yield) of (*Z*)-9-tetradecenol (90% pure) was obtained.

(b) Pure methyl (*Z*)-9-tetradecenoate, 2.4 g (0.01 mol) was reduced as described above to afford 2.0 g (95% yield) of pure (*Z*)-9-tetradecenol, m.p. −28 to −26 °C, $CST_{(MeNO_2)}$ 55 °C.

*Tetradecenyl acetate* was prepared from the concentrate (a) and from pure (b) methyl tetradecenoate following an established procedure [5].

(a) An aliquot of the concentrate of methyl tetradecenoate, 26 g (0.11 mol), dissolved in 100 ml of anhydr. diethyl ether, was added dropwise to a solution of 7.5 g (0.2 mol) of lithiumaluminumhydride in 200 ml of anhydr. diethyl ether. The reaction mixture was heated to reflux under magnetic stirring for 4 h. After evaporation of most of the solvent, 2.5 g (0.25 mol) of acetic anhydride was added dropwise, and the mixture was heated gently to remove the rest of the diethyl ether. The reaction mixture was then heated to reflux for 3 h after which time excess acetic anhydride was decomposed by the addition of ethanol. The mixture was heated for another hour, then cooled to room temperature and dissolved in 200 ml of diethyl ether. This solution was washed with several portions of water, until neutral, and dried over anhydr. sodium sulfate. After evaporation of the solvent, 29.5 g (95% yield) of (*Z*)-9-tetradecenyl acetate (90% pure) was obtained.

(b) Pure methyl (*Z*)-9-tetradecenoate, 2.4 g (0.01 mol) was reduced and the intermediate alcohol

acetylated as described above to afford 2.4g (85%) of pure (*Z*)-9-tetradecenyl acetate, m.p. −30 to −28.5 °C, ($CST_{(MeNO_2)}$) < −50 °C.

*Tetradecenal* was prepared from the concentrate (a) and from pure (b) methyl tetradecenoate *via* tetradecenol and tetradecenyl methanesulfonate [6, 7].

(a) An aliquot of tetradecenol, 50g (0.23mol) that had been obtained by lithiumaluminumhydride reduction of the concentrate, was reacted with 40 g (0.3 mol) of methanesulfonyl chloride in 20 ml of anhydr. pyridine. The reaction mixture was stirred, first at 5 °C and then at room temperature for 5 h. The reaction product was dissolved in 400 ml of diethyl ether and 300 ml of water under continued stirring. The organic layer was washed consecutively with water, 2 N sulfuric acid, until acidic, 1% potassium carbonate solution, until basic, and water. After drying of the solution over anhydr. sodium sulfate and evaporation of the solvent, 34.5 g (50% yield) of (*Z*)-9-tetradecenyl methanesulfonate (90% pure) was obtained.

Because of the instability of the desired aldehyde, only small amounts of the methanesulfonate were oxidized. Thus, a mixture of tetradecenyl methanesulfonate, 3 g (0.01 mol), 1.5 g of sodium bicarbonate and 15 ml of dimethyl sulfoxide was heated to 170 °C for 10 min under stirring. The reaction mixture was rapidly cooled to room temperature and poured into 250 ml of ice water. The lipophilic reaction products were extracted with three 100 ml portions of diethyl ether, the combined extracts were washed with water and dried over anhydr. sodium sulfate. After evaporation of the solvent, and chromatography of the residue on a column of silica gel, 1.8 g (80% yield) of (*Z*)-9-tetradecenal (90% pure) was obtained.

(b) Pure methyl (*Z*)-9-tetradecenoate, 2.4 g (0.01 mol) was reduced to the alcohol which was converted *via* the methanesulfonate to 1.2 g (80%) of pure (*Z*)-9-tetradecenal, m.p. −42 to −39 °C, $CST_{(MeNO_2)}$ < −50 °C.

## Results and Discussion

We have developed a convenient procedure for the isolation of relatively large amounts of tetradecenoic acid from the total fatty acids of beef tallow. A combination of fractional distillations and crystallizations and subsequent esterification affords a concentrate of methyl tetradecenoate containing about 3.5% of methyl myristate and 5% of methyl isomyristate. Pure methyl tetradecenoate is easily isolated from this concentrate by argentation chromatography.

The chain length of the fatty acid we have isolated and the presence of a single double bond were established by the behavior of the methyl ester in gas chromatography before and after its catalytic hydrogenation. The (*Z*)-configuration of the double bond was proven by an infrared spectrum of the methyl ester, which showed the bands to be expected for such a long-chain unsaturated compound, but did not exhibit absorption near 965 $cm^{-1}$, which is associated with (*E*)-C-H out-of-plane deformation. The position of the double bond was established by reductive ozonolysis followed by gas chromatography of the aldehydes and aldesters formed. From the data obtained it must be concluded that the material we have isolated consists of (*Z*)-9-tetradecenoic acid. Several positional isomers of this fatty acid are present in our preparation at levels of 1% or less.

The concentrate of methyl (*Z*)-9-tetradecenoate as well as the pure compound have been converted, in excellent yields, to (*Z*)-9-tetradecenol and (*Z*)-9-tetradecenyl acetate. In the preparation of (*Z*)-9-tetradecenal *via* the corresponding alcohol and alkyl methanesulfonate, the over-all yield is not as good; it could probably be considerably improved by oxidizing (*Z*)-9-tetradecenol directly with dimethyl sulfoxide containing chromium trioxidepyridine complex [8].

The three pairs of preparations are being tested in the field for their activity as pheromones. It is hoped that the preparations obtained by reactions of the concentrate of methyl (*Z*)-9-tetradecenoate will exhibit activities similar to those observed with the pure compounds. This would encourage the large-scale production of such pheromones from the total fatty acids of beef tallow and their use in the biological control of insect pests.

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