# Synthesis of Long Chain Alkyl Glyceryl Ethers from Triglycerides Using Boron Trifluoride Etherate and Lithium Aluminum Hydride

## ABSTRACT

A procedure for direct conversion of long chain triglycerides to their corresponding ether derivatives has been accomplished using a combination of lithium aluminum hydride and boron trifluoride etherate. Reaction products obtained from reduction of tristearin or trimyristin were isolated by thin layer and column chromatography and identified using infrared spectroscopy. Glyceryl triethers, glyceryl monoethers, and aliphatic alcohols were the major reaction products, making up 2-3%, 9-19%, and 43-75%, respectively, of the theoretical molar yields. Yields of both ether derivatives were increased when a lithium aluminum hydride solution was added to a mixture of triglyceride and boron trifluoride etherate rather than adding a mixture of triglyceride and boron trifluoride etherate to lithium aluminum hydride. Increasing the quantities of lithium aluminum hydride increased glyceryl triether yield, but decreased glyceryl monoether yield.

## INTRODUCTION

Previous studies have indicated that glyceryl triethers, unlike glycerides, are neither hydrolyzed nor absorbed when fed to rats (1-3). Because of the low absorption of glyceryl triethers and their structural similarities to natural fats and oils, it is possible that these compounds could be used to decrease the total caloric value of food products, while providing the desired functional characteristics in food products. To make this use possible, however, these compounds must be easily and inexpensively produced.

Glyceryl triethers normally are synthesized by the stepwise procedure outlined by Bauman and Mangold (4,5). A conceivably less expensive procedure would be the conversion of an inexpensive fat or oil directly to glyceryl triethers. Pettit and Piatak (6) have reported that isomeric butyl esters of cholanic acid can be converted directly to the corresponding ether derivatives by using a combination of boron trifluoride etherate and lithium aluminum hydride. The purpose of the study reported herein was to evaluate the use of boron trifluoride and lithium aluminum hydride for direct conversion of triglycerides to their corresponding triethers.

## EXPERIMENTAL PROCEDURE

Pettit, et al., (6-8) reported optimum reduction of lactones using 30 moles of boron trifluoride etherate (BFE) and 2 moles of lithium aluminum hydride (LAH) per mole of lactone compound having one ester group. Thus, 4.5 mmoles of trimyristin or tristearin and 405 mmoles of BFE were dissolved in 55 ml tetrahydrofuran. This mixture then was added under nitrogen pressure to a solution containing different quantities of LAH (15, 27, and 40 mmoles) in diethyl ether, or conversely, a standard 0.7828 M of LAH was added dropwise to this mixture. After 45 min at ice-salt bath temperatures (10 C) and refluxing for 2 hr, the mixture was hydrolyzed with 10% hydrochloric acid until 2 layers were formed. The ethereal phase was separated and the aqueous portion subsequently extracted, in sequence,

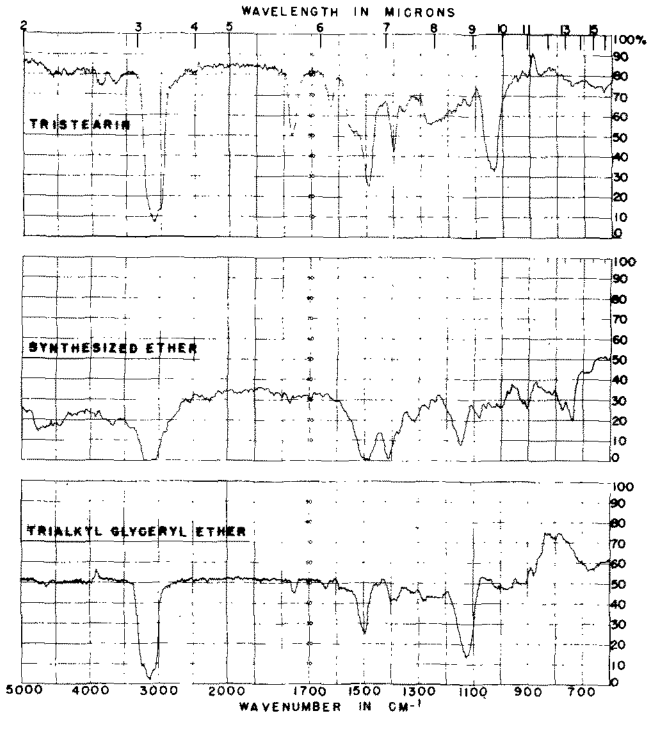

FIG. 1. Infrared spectra of standard tristearin (top), synthesized glyceryl triether (middle) from tristearin, and standard glyceryl triether of 1-hexadecoxy-2,3-didodecoxypropane (bottom).

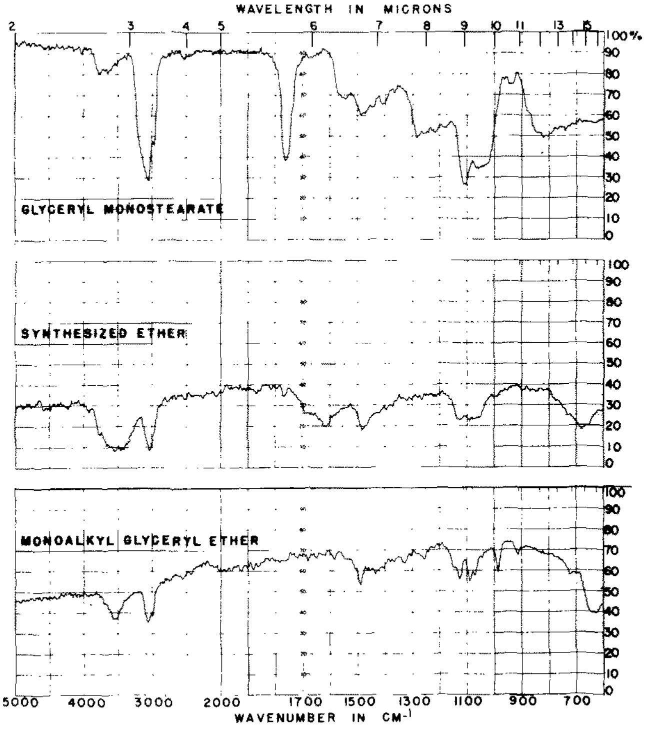

FIG. 2. Infrared spectra of standard glyceryl monostearate (top), synthesized glyceryl monoether (middle) from tristearin, and standard glyceryl monoether of 2-octadecoxy-1,3-propanediols (bottom).

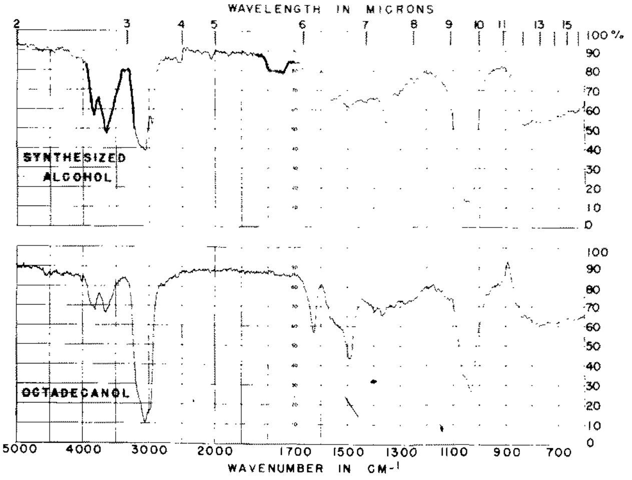

FIG. 3. Infrared spectra of synthesized alcohol (top) from tristearin and standard octadecanol (bottom).

with ether, chloroform, and chloroform:ethanol (9:1). The combined extracts then were washed with distilled water, a saturated sodium bicarbonate solution, and a saturated sodium chloride solution. The washed extracts were concentrated and subjected to either saponification using potassium hydroxide (KOH) or to hydrogenolysis using LAH. This procedure removed any remaining esterified fatty acids. Thompson, et al., (9) reported that saponification or hydrogenolysis were equally effective in removing the acyl ester linkages on α-glyceryl ether containing lipid material. However, hydrogenolysis was achieved in a shorter time. The reaction products then were subjected to thin layer chromatography (TLC) on silica gel for product separation and identification.

Samples for infrared (IR) analysis were further purified using 2-dimensional chromatography (chloroform methanol; 95:5), followed by hexane:diethyl ether:acetic acid (60:40:1, v/v). The sample zones on the chromatogram were scraped into vials containing KBr wick-sticks (Harshaw Chemical Co., Cleveland, Ohio). The wick was pressed into micropellets and analyzed using a Beckman IR-4 (Beckman Instrument Co., Fullerton, Ca.). One-dimensional ascending TLC on silica gel G was used to separate reduction products. Chloroform:methanol (95:5, v/v), hexane diethyl ether:acetic acid (70:30:1, v/v) or hexane:diethyl ether:acetic acid (60:40:1, v/v) were used as developing solvents.

Samples for mass spectrometric analysis were purified using silicic acid column chromatography (1,10). Samples eluted with 50% benzene (same $R_f$ as the standard glyceryl triether) were combined, evaporated to dryness, and analyzed by mass spectrometry (Associated Electrical Industries Ltd., Manchester, England) at 230 C.

## RESULTS

Analysis by TLC in 3 solvent systems revealed that 3 reaction products were formed from treatment of tristearin with LAH plus BFE followed by LAH hydrogenolysis or saponification by KOH. Based on $R_f$'s on TLC and IR spectra, (Fig. 1,2,3), the reaction products were identified as glyceryl monoether, glyceryl triether, and octadecanol. Mass spectral analysis verified the identity of the glyceryl triether product. No other glyceryl ethers could be isolated identified by the procedures used.

Treatment of trimyristin or tristearin with LAH plus BFE followed by LAH hydrogenolysis yielded only a small percentage of glyceryl triethers with a slightly higher percentage of glyceryl monoether (Table I). As would be expected, the major reaction product was the alcohols. It is not known how much alcohol was produced from the LAH-BFE reduction or the LAH hydrogenolysis. The yields of glyceryl triethers were slightly higher when LAH was added to the mixture of triglycerides and BFE rather than the reverse addition. Increasing or decreasing the moles of LAH did not increase significantly the yield of glycerol triethers from tristearin.

## DISCUSSION

Based on analyses by TLC and IR and mass spectrometry, reduction of either trimyristin or tristearin with LAH followed by LAH hydrogenolysis or KOH saponification resulted in the formation of the respective glyceryl triether, glyceryl monoether, and alcohol. Because of the low yield of glyceryl triether, this reduction would not appear to be useful for direct production of triethers from triglycerides. Although the modifications of the reduction attempted in this work did not increase yields, other modifications might be helpful. For example, introduction of alkyl branching of the α-positions of the triglycerides prior to reduction might increase triether yields. Pettit's work (6-8) has shown that

TABLE I

Yield of Glyceryl Ethers Resulting from Reduction of Tristearin and Trimyristin

| | | | | Yield (%)[b] | | | |
|---|---|---|---|---|---|---|---|
| Substrate | Ratio[a] | Reaction solvent | Mode of addition | Monoether | Triether | Total glyceryl ether | Alcohol |
| Tristearin | 4.5:15:405 | Tetrahydrofuran | TG + BFE added to LAH | 19.2 | 2.4 | 21.6 | 62.0 |
| | 4.5:27:405 | Tetrahydrofuran | TG + BFE added to LAH | 11.3 | 1.9 | 13.2 | —[c] |
| | 4.5:40:405 | Tetrahydrofuran | TG + BFE added to LAH | 11.3 | 3.1 | 14.4 | 60.0 |
| Tristearin | 4.5:27:405 | Tetrahydrofuran | LAH added to TG + BFE | 13.5 | 2.8 | 16.3 | 43.5 |
| Trimyristin | 4.5:27:405 | Diethyl ether | TG + BFE added to LAH | 9.2 | 2.2 | 11.3 | 67.1 |
| Trimyristin | 4.5:27:405 | Diethyl ether | LAH added to TG + BFE | 17.8 | 3.4 | 21.2 | 75.7 |

[a] Mole ratio of triglyceride (TG):lithium aluminum hydride (LAH):boron trifluoride etherate (BFE).

[b] % based of the theoretical yield from TG, i.e., 1 mole yield of triether per mole of TG, 1 mole yield of monoether per mole of TG, and 3 moles of alcohol per mole of TG.

[c] Sample lost.

increased branching at the ester group increases ether formation in the $BF_3$-LAH reduction system.

The relatively higher yield of monoether formed in this reduction might have some utility. It is possible that the $BF_3$-LAH reduction system could be used for conversion of crude fats and oils to glyceryl monoethers and alcohols, which could then be converted to triethers by conventional techniques (4,5). In any event, much work remains before commercial application of the process to food products is possible.

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## ACKNOWLEDGMENTS

This work was supported in part by research grants from the Graduate School and the College of Agriculture and Life Sciences of the University of Wisconsin, Madison, WI. Mass spectrometry of compounds was done by H.K. Schnoes.

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[Received May 29, 1975]