☘Reduction of Unsaturated Fatty Acids and Fatty Alcohols with Diimide from Hydroxylamine-Ethyl Acetate

A. GANGADHAR, R. SUBBARAO and **G. LAKSHMINARAYANA,*** Regional Research Laboratory (CSIR), Hyderabad - 500007, India

ABSTRACT

Hydroxylamine has been recently found to react with ethyl acetate to generate diimide in situ. This reaction was used to reduce 10-undecenoic, oleic, linoleic, stearolic, concentrates of ricinoleic, cyclopentene and cyclopropene fatty acids (FA), dehydrated castor oil FA, 10-undecen-1-ol, oleyl alcohol and castor fatty alcohols. Unsaturated FA and their corresponding alcohols reacted in a similar manner. Terminally unsaturated, cyclopropene and cyclopentene FA were more reactive than oleic acid, which, in turn, was more reactive than hydroxymonoenoic acids. Conjugated dienoic FA reduced faster than nonconjugated dienoic acids. Partial hydrogenation using this reagent is particularly advantageous in determining geometry and the position of double bonds in the polyunsaturated FA, as it can be carried out in the absence of oxygen or oxidizing agents unlike hydrazine reductions.

INTRODUCTION

Partial reduction of polyunsaturated compounds with diimide generated in situ from different reagents (1-4) leads to saturation of some double bonds without affecting the position and configuration of the remaining double bonds, unlike in catalytic hydrogenation (5-7). The most commonly used diimide-generating reagent for determining the position and configuration of double bonds in polyunsaturated fatty acids (FA) is hydrazine (7). Recently a combination of hydroxylamine hydrochloride and sodium acetate was used for decarboethoxylation of ethyl 2-nitro-5-phenyl-4-pentenoate (8). This reagent, in addition to affecting decarboethoxylation, also reduced the double bond. This observation led to the use of hydroxylamine hydrochloride with ethyl acetate for the in situ generation of diimide as shown in Figure 1.

Reduction of a few short-chain unsaturated compounds (cinnamyl alcohol, cinnamic acid, 1-decene, 2-decene-1-ol and diphenylacetylene) was reported (8) using this reagent. In the present communication we report the use of this reagent for reducing various long-chain unsaturated FA and fatty alcohols.

MATERIALS AND METHODS

10-Undecenoic acid was purchased from M/s. Jayant Oil Mills, Bombay, India. Methyl oleate and methyl linoleate were purchased from Sigma Chemical Co., St. Louis, MO. The mixed FA of castor oil and *Sterculia foetida* oil were prepared by saponification at room temperature followed by acidification in the presence of diethyl ether. The FA of castor oil were immediately used for reduction. A concentrate of cyclopropene fatty acids (CFA) was prepared by urea adduction of mixed acids of *S. foetida* oil (9). Stearolic acid was prepared by bromination of oleic acid followed by dehydrobromination of the resulting dibromide (10). Dehydrated castor oil (DCO) FA were prepared by decomposition of estolides of castor oil FA (11). 10-Undecen-1-ol, oleyl alcohol and castor fatty alcohols were prepared by lithium aluminum hydride reduction of methyl esters of the corresponding FA (12). A concentrate of hydnocarpic (22.3%) and chaulmoogric (77.7%) acids was obtained by conventional methods from the methyl esters of *Hydnocarpus wightiana* seed oil (13-15). Methoxy derivatives of monoenoates were prepared according to the procedure of White (16).

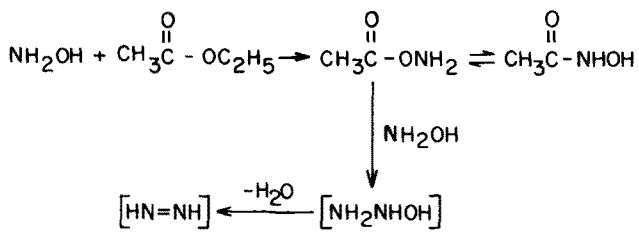

FIG. 1. Mechanism of diimide generation from hydroxylamine-ethyl acetate (8).

The reduction procedure consisted of adding powdered potassium hydroxide (33 g) to a mechanically stirred solution of hydroxylamine hydrochloride (34.75 g; 0.50 mol) in dimethylformamide (100 mL) at 25-30 C, under nitrogen. The resulting mixture was stirred for 15 min and filtered. The filtrate (pH 8-9) was cooled in an ice bath and ethyl acetate (19.59 g; 0.22 mol) was added. The ethyl acetate-hydroxylamine solution was added to oleic acid (2.82 g; 0.01 mol unsaturation) over a period of 1.5 hr at 90-95 C and the contents were heated for an additional hour under nitrogen while stirring. At the end of the reaction, the contents were cooled to room temperature, added to water, acidified with dilute sulfuric acid and extracted with diethyl ether. All the monoenoic compounds were reduced under identical conditions. Linoleic acid, DCO FA and stearolic acid, when used in an amount equivalent to 0.02 mol unsaturation, yielded partially hydrogenated products that, on a second reduction using the same quantity of reagent, provided fully hydrogenated products. In a few experiments the amount of reagent was appropriately scaled down to reduce ca. 300 mg quantity of unsaturated compound.

Thin layer chromatography (TLC) on Silica Gel G (ACME Synthetic Chemicals, Bombay, India) using a mixture of gasoline (40-60 C)/diethyl ether/ethyl alcohol/acetic acid (60:40:4:1, v/v/v/v) was carried out to detect the presence of estolides in the reduced products of castor oil FA (17). The unsaturated fatty alcohols and FA methyl esters were analyzed by gas liquid chromatography (GLC) using a Hewlett-Packard 5840 A unit equipped with a flame ionization detector (FID), a glass column (1.8 m × 6 mm) packed with 10% Silar 10 C/Gas Chromosorb W HP (100-120 mesh) and a data processor. The column, injection port and detector temperatures were maintained at 150 C, 250 C and 300 C for C11 compounds and at 200 C, 250 C and 300 C for C18 compounds. The flow rate of nitrogen was 30 mL/min. Methyl esters of castor oil FA and their reduction products were analyzed as trimethylsilyl ether derivatives using bis-(trimethylsilyl) trifluoroacetamide on an EGSS-X/Gas Chrom Q (80-100 mesh) column. The CFA in the starting material and in the final products were determined by conversion into stable ether and keto derivatives using methanolic silver nitrate reagent (18) before GLC analysis. The areas of peaks from ether and keto derivatives as well as the unidentified component from the respective CFA were combined to calculate the percentage of composition.

Proton nuclear magnetic resonance (PMR) spectra were recorded in $CDCl_3$ solution using a JEOL FX 90Q Fourier

*To whom correspondence should be addressed.

Transform NMR spectrometer. Tetramethylsilane was used as an internal standard. Infrared (IR) spectra were recorded in CS_2 solution using a Perkin-Elmer Model 283 B spectrophotometer. Mass spectra (MS) (70eV) were determined on a V.G. Micromass 7070 H mass spectrometer.

RESULTS AND DISCUSSION

Compositions of the starting fatty materials as well as the products are given in Tables I and II. Terminal double bonds were reduced faster than the internal double bonds as shown by the reduction of 10-undecenoic acid and oleic acid, and 10-undecenol and oleyl alcohol. The reduction proceeded almost to the same extent for the monoenoic acids and the corresponding alcohols. Linoleic acid was hydrogenated faster than oleic acid and yielded a mixture of stearic and isomeric oleic acids and unconverted linoleic

TABLE I

Reduction of Unsaturated Fatty Acids and Fatty Alcohols Using Hydroxylamine-Ethyl Acetate

Fatty material	Purity composition (%)[a]	Product composition (%)[a]	
10-Undecenoic acid	98.9	Undecanoic acid	97.9
		10-Undecenoic acid	1.0
10-Undecen-1-ol	99.1	Undecanyl alcohol	98.7
		10-Undecenyl alcohol	0.4
Oleic acid	99.5	Stearic acid	84.9
		Oleic acid	14.6
Linoleic acid	99.7	Stearic acid	60.8
		Isomeric oleic acids	33.7
		Linoleic acid	5.2
Stearolic acid	98.8	Stearic acid	39.5
		Oleic acid	21.9
		Stearolic acid	37.4
Oleyl alcohol	99.0	Stearyl alcohol	86.0
		Oleyl alcohol	13.0
Castor oil fatty acids			
16:0	2.0	16:0	2.2
18:0	2.0	18:0	6.8
18:1	3.0	18:1	2.0
18:2	3.0	18:2	0.0
18:1(OH)	90.0	18:0(OH)	68.0
		18:1(OH)	21.0
Castor oil fatty alcohols			
16:0	1.4	16:0	1.1
18:0	1.6	18:0	8.1
18:1	4.9	18:1	1.6
18:2	2.8	18:2	0.0
18:1(OH)	89.3	18:0(OH)	66.1
		18:1(OH)	23.1

[a]By gas chromatography.

TABLE II

Comparative Reduction of Various Unsaturated Fatty Acids with Hydroxylamine-Ethyl Acetate

Fatty acids	Purity composition (%)[a]	Product composition (%)[a]			
			1.5 hr	2 hr	2.5 hr
Oleic acid	99.5	18:0	35.4	69.1	82.4
		18:1	64.1	30.4	17.1
Concentrate of cyclopentene fatty acids					
Hydnocarpic	22.3	Dihydrohydnocarpic	12.2	22.4	22.3
Chaulmoogric	77.7	Hydnocarpic	10.4	0.0	0.0
		Dihydrochaulmoogric	40.7	74.7	76.7
		Chaulmoogric	36.7	2.9	1.0
Concentrate of cyclopropene fatty acids					
18:0	0.8	18:0	3.5	9.5	10.5
18:1	0.8	18:1 + Dihydromalvalate	16.0	12.3	11.3
18:2	7.2	18:2 + Dihydrosterculate	66.6	69.0	74.5
Malvalate	11.9	Malvalate	0.5	0.0	0.0
Sterculate	79.3	Sterculate	13.4	9.2	3.7
DCO fatty acids					
16:0	2.2		2.1	2.0	2.1
18:0	2.2		5.7	17.4	25.3
18:1	6.2		26.2	38.5	39.8
18:2 (nonconjugated)	27.5		17.6	7.6	4.7
18:2 (conjugated)	61.9		48.4	34.5	28.1

[a]By gas chromatography.

acid. Stearolic acid was reduced only 60%, giving stearic, oleic and unconverted stearolic acids. The IR spectra of the total products derived from oleic, linoleic and stearolic acids showed no *trans* unsaturation, indicating that the reduction was stereoselective. Silver ion TLC of the methyl esters of the partially reduced product of linoleic acid followed by GLC of the separated fractions using methyl heptadecanoate as an internal standard showed ca. 1% formation of *trans*-monoenoate compared with 32% *cis*-monoenoates. Derivatization of the *cis*-monoenoate fraction to methoxystearate by methoxymercuration–demercuration followed by study of MS fragmentation (19) showed that the *cis*-monoenoate fraction was a mixture of only 9- and 12-isomers. The hydroxylamine-ethyl acetate reagent, as a diimide generating agent, can therefore be used for the structure elucidation of nonconjugated polyenoic acids because the reagent did not alter the configuration or position of the original double bond that was not reduced.

A comparison of the acid values of starting castor oil FA (A.V. 186.4) with the reduced product (A.V. 183.0) showed that there was little or no estolide formation. This was further confirmed by silica gel TLC. The data obtained on castor FA, castor fatty alcohols and their reduction products show that the acids and alcohols were reduced almost to the same extent and were less reactive than oleic acid or oleyl alcohol.

The concentrate of CFA (91.2%) was reduced and samples at different intervals were analyzed. The compositions are given in Table II. A comparison of data shows that CFA were reduced faster than oleic acid. The PMR spectrum of the final product showed the presence of protons for the cyclopropanoid moiety (0.6 ppm δ). A second reduction provided a fully hydrogenated product free of olefinic and cyclopropene protons as shown by PMR. A comparison of the FA composition of the starting material and of the fully hydrogenated product showed only ca. 2% loss of CFA under the conditions of reduction and this loss could be caused by polymerization of CFA.

A comparison of the data obtained using a mixture of hydnocarpic (22.3%) and chaulmoogric (77.7%) acids shows that the cyclopentene FA were also reduced faster than oleic acid. The results are summarized in Table II. Accordingly, the reagent provides a good procedure for preparing cyclopropane and cyclopentane FA from cyclopropene and cyclopentene FA, respectively.

The reduction of DCO FA, equivalent to an amount containing 0.02 mol unsaturation, yielded a partially hydrogenated product having 16:0 (2.1%), 18:0 (25.3%), 18:1 (39.8%), 18:2 nonconjugated (4.7%) and 18:2 conjugated (28.1%) FA. A comparison of the reduction in the nonconjugated and conjugated FA contents showed that the conjugated FA were reduced faster than the nonconjugated FA (Table II). A second reduction of the product using the same quantity of the reagent gave a product containing 16:0 (2.4%), 18:0 (93.0%), 18:1 (4.0%) and 18:2 conjugated (0.6%).

Hitherto, only hydrazine has been used in structural determination of polyunsaturated FA through partial reduction. Hydroxylamine-ethyl acetate could be an alternative reagent for partial reduction of polyunsaturated FA as these can be conveniently reduced to the desired extent by using requisite amounts of the reagent and unsaturated compound. This reagent has an additional advantage over hydrazine hydrate as the reaction can be carried out in the absence of oxygen or oxidizing agents.

ACKNOWLEDGMENT

The Council of Scientific and Industrial Research (CSIR), India, provided a research fellowship to A. Gangadhar.

REFERENCES

1. Hunig, S., H.R. Muller and W. Thier, Angew. Chem. Intern. Ed. 4:271 (1965).
2. Miller, C.E., J. Chem. Ed. 42:254 (1965).
3. Kondo, K., S. Murai and N. Sonoda, Tetrahedron Lett. 3727 (1977).
4. Nagendrappa, G., and D. Devaprabhakara, Ibid. 4243 (1970).
5. Scholfield, C.R., E.P. Jones, J. Nowakowska, E. Selke and H.J. Dutton, JAOCS 38:208 (1961).
6. Corey, E.J., D.J. Pasto and W.L. Mock, J. Am. Chem. Soc. 83: 2957 (1961).
7. Aylward, F., and M. Sawistowska, Chem. & Ind. 484 (1962).
8. Wade, P.A., and N.V. Amin, Syn. Comm. 287 (1982).
9. Nunn, J.R., J. Chem. Soc. 313 (1952).
10. Adkins, H., and R.E. Burks, Organic Synthesis 27:76 (1947).
11. Lakshminarayana, G., R. Subbarao, Y.S.R. Sastry, T. Chandrasekhara Rao, V. Kale and P. Vijayalakshmi, JAOCS 59:238 (1982).
12. Brown, W.G., Org. React. 6:469 (1951).
13. Zeman, I., and J. Pokorny, J. Chromatogr. 10:15 (1963).
14. Mani, V.V.S., and G. Lakshminarayana, Ibid. 39:182 (1969).
15. Richter, I., and G. Lakshminarayana, Chem. Phys. Lipids 25:191 (1979).
16. White, H.B., J. Chromatogr. 21:213 (1966).
17. Neissner, R., Fette Seifen Anstrichm. 82:183 (1980).
18. Scheneider, E.L., S.P. Loke and D.T. Hopkins, JAOCS 45:585 (1968).
19. Minnikin, D.E., P. Abley and F.J. Mcquillin, Lipids 9:135 (1974).

[Received December 6, 1983]