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Summary

In a study of the catalytic vapor phase oxidation of crotonaldehyde to maleic acid a conversion of 44.2% was obtained.

Two forms of vanadium pentoxide catalyst were used, one deposited on aluminum balls as carriers, the other on pumice. The form of catalyst having the higher thermal conductivity, *i. e.*, that deposited on aluminum, yielded higher conversions.

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[Contribution from the Laboratory of Physiological Chemistry, The Ohio State University]

Studies on the Chemistry of the Fatty Acids. III. The Properties of Linoleic Acids Prepared by Debromination and by Low Temperature Crystallization, with a Proposed Method of Quantitative Estimation[1]

By J. B. Brown and Jerome Frankel

In a previous report[2] procedures for the preparation of linoleic acid were described, based on fractional crystallization of the fatty acids of corn and cottonseed oils from several organic solvents. By a refinement of this method we have been able to prepare a relatively large amount of linoleic acid of better than 93% purity from corn oil. The question naturally arose as to whether this preparation was identical chemically with the so-called α-linoleic acid previously described in the literature by Rollett,[3] and others.[4]

The question is important because the only method previously successful in making the pure acid is that of Rollett which involves the classic bromination–debromination process and which necessarily introduces the question of tetrabromide and linoleic acid isomerism. Accordingly we have prepared some of the pure α-acid by Rollett's procedure, and have compared its properties with those of the acid prepared by crystallization. Although the latter naturally was more impure, we have found that so far as melting point, refractive index and tetrabromide number are concerned, there is little doubt that the two acids are identical.

When α-linoleic acid is brominated in petroleum ether it yields insoluble bromides equal to 90.6% of its original weight; the theoretical is 214%. Hence more than half of the resultant bromides are soluble. When the filtrate from these insoluble bromides is cooled to −70°, they partially precipitate as viscous oils. This formation of soluble bromides was originally noted by Rollett and is a general property of fatty acids with two or more double bonds. Ault and Brown,[5] working with arachidonic acid, took advantage of this fact in proposing a formula for quantitative estimation of arachidonic acid, based on a comparison of the octabromide number of the pure acid (prepared by bromination–debromination) with the octabromide number of a given fatty acid mixture. We wish to propose a similar formula for the estimation of linoleic acid, as follows

$$\text{Per cent. linoleic acid} = \text{T. N.} \times 100/90.6$$

where T. N. is the percentage yield of petroleum ether insoluble tetrabromides given by the fatty acid mixture under investigation and 90.6 is the tetrabromide number of a specimen of pure α-linoleic acid.

The yield of insoluble tetrabromides is naturally involved in the problems of *cis–trans* isomerism in the instance of the original acid and of optical isomerism as far as the products are concerned. It is reasonably certain that in our pure preparations we are dealing with a single *cis–trans* configuration,[6] probably *trans,trans*-9-10,12-13-octadecadienoic acid. Upon bromination, it is likely, though not proved, that at least two pairs of enantiomorphs result, one of which is quite insoluble and high melting; the other pair is very soluble and low melting. Apparently, they are formed in almost equal amount. If they were

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[1] Presented at the Fall Meeting of the American Chemical Society, 1937, Rochester, N. Y.

[2] Brown and Stoner, This Journal, **59**, 3 (1937).

[3] Rollett, *Z. physiol. Chem.*, **62**, 410 (1909).

[4] Holde and Gentner, *Ber.*, **58**, 1067 (1925); Birosel, This Journal, **59**, 689 (1937).

[5] Ault and Brown, *J. Biol. Chem.*, **109**, 615 (1934).

[6] Smith and West, *Philippine J. Sci.*, **32**, 297 (1927).

formed in equal amount the tetrabromide number would be 107. The fact that it is as low as 90.6 is probably due in part to unavoidable slight solubility of the solid tetrabromide in petroleum ether, and in part to the formation of more liquid bromide than solid.

Concerning the accuracy of the above method we are not prepared to give a final answer, except to point out that, as a means of estimating α-linoleic acid, it is directly positive in contrast to the lack of specificity of the thiocyanogen–iodine number calculation. The older direct procedure of weighing the tetrabromides and calculating their fatty acid content invariably gives results of less than half those obtained by the proposed method. This method unavoidably will give low results if too small samples are used, or, if the specimen contains relatively small amounts of the acid, conditions which will exaggerate the unavoidable error of solubility in the wash liquid. The use of petroleum ether saturated with pure tetrabromostearic acid as wash liquid may tend to improve the accuracy of the procedure. Another condition that must be controlled rigidly is the bromination temperature, as this may seriously affect the yield of tetrabromides.

Experimental Part

Preparation of α-Linoleic Acid.—The unsaturated fatty acids of corn oil were brominated in cold ether. After removal of excess bromine by washing with sodium thiosulfate solution, drying and distilling off most of the ether, the tetrabromides were recovered by precipitation with petroleum ether. They were purified by crystallization four times from petroleum ether at −20°. The tetrabromides contained 52.9% bromine (calcd. 53.3) and melted at 114.5°. One hundred and eighty-five grams of these bromides was added gradually to 1500 cc. of hot 95% alcohol and 200 g. of zinc powder in a 3-liter flask. A few drops of concd. hydrochloric acid was added from time to time to catalyze the reaction. The heat of reaction kept the alcohol boiling. When all of the bromides had been added, the contents of the flask were refluxed for thirty minutes to complete the reaction. The alcohol solution was filtered and acidified with hydrochloric acid to decompose any zinc soap present. Three-fourths of the alcohol was removed under reduced pressure. Water and ether were added, the ether layer was separated and the ether distilled. The resulting mixture of linoleic acid and ethyl ester was distilled under reduced pressure. The product was saponified with alcoholic potassium hydroxide, and the pure linoleic acid recovered and distilled. The constants are found in Table I below.

Preparation of Linoleic Acid by Low Temperature Crystallization.—The details of preparation from corn oil are essentially those described previously.[2] Two kilograms of the unsaturated acids of corn oil, prepared by the −20° acetone procedure (about 67% linoleic), was dissolved in acetone (75 g./l.) and crystallized in 2-liter batches at −50° in a bath of dry ice and alcohol. The crystals were filtered rapidly and the filtrate cooled to −70°. The resultant crystals were warmed under reduced pressure to remove the acetone and distilled at 2–3 mm. About 70–80 g. of undistilled acids was allowed to remain in the distilling flask. The yield was 380 g., which, calculating from the iodine number as a mixture of oleic acid and linoleic acid, gave the purity as about 93.5%. Other analyses are given in Table I.

TABLE I

COMPARISON OF LINOLEIC ACID PREPARATIONS

	α-Linoleic acid	Crystallization linoleic acid
Iodine no. (Wijs)	180.9	175.0
Purity from I_2 no.	100	93.5
Mean mol. wt.	282.9	281.5
Tetrabromide no.	90.6[a]	86.8
Purity from tetrabromide no.	100	95.8
n^{20}	1.4691	1.4682
M. p., °C.	−6.8[b]	−7.0
Mixed m. p., °C.		−6.8

[a] Theoretical tetrabromide number, 214. [b] Holde and Gentner reported a m. p. of −8 to −7°.

Comparison of the Two Linoleic Acid Preparations.—Analytical constants of the acids described above are given in Table I. The melting point determinations were made on specimens which had been kept at −20° overnight. A Bureau of Standards thermometer was employed. Both specimens melted sharply.

Suggested Procedure for Determination of the Amount of Linoleic Acid in Mixtures of Fatty Acids.—As a basis for the above suggested method

TABLE II

TETRABROMIDE NUMBERS OF VARIOUS PREPARATIONS OF LINOLEIC ACID

Description of preparation	Iodine no.	Wt. sample, g.	Wt. bromide, g.	Tetrabromide no.	α-Linoleic from formula, %
α-Linoleic	180.9	1.6697	1.5050	90.1	
		1.6955	1.5905	93.8	
		1.6585	1.4942	90.1	
		1.5554	1.3727	88.3	
				Av. 90.6	100
		3.1310	2.7197	90.1	
		3.4920	3.0130	86.3	
Linoleic by cryst.	175.0	1.6490	1.4458	87.7	
		1.6846	1.4597	86.5	
		1.6964	1.4736	86.8	
		1.4945	1.3045	87.1	
				Av. 87.0	96.0
Linoleic by cryst.	166.0[a]	1.6264	1.2662	77.8	
		1.5984	1.2730	79.8	
				Av. 78.8	85.9
Fatty acids corn oil (not distilled)	137.5	2.7820	1.3760	49.5	
		2.7200	1.3773	50.6	
				Av. 50.1	55.3

[a] Purity from iodine number, 83.5%.

for estimating linoleic acid, we wish to present data based on the following procedure for determination of tetrabromide number. Weigh a 1.5–2.0 g. sample of fatty acids into a tared 50-cc. centrifuge tube. Add at once 30–35 cc. of low-boiling petroleum ether. Place the tube in an ice-salt bath and, with constant stirring, add dropwise an excess of bromine. Allow to stand at 0° for at least four hours and centrifuge. Add 30 cc. of cold petroleum ether, disintegrate the bromides and stir for five to ten minutes in an ice-water bath. Repeat this washing three times. Dry the resultant tetrabromides to constant weight, and weigh. The results obtained are given in Table II.

Summary

1. A procedure for the preparation of linoleic acid by fractional crystallization of the fatty acids of corn oil is described.

2. The properties of the acid prepared by crystallization are compared with those of pure α-linoleic acid.

3. A method of quantitative estimation of linoleic acid, based on the determination of its tetrabromide number, is proposed and discussed.

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[CONTRIBUTION FROM THE INSTITUTE OF EXPERIMENTAL BIOLOGY, UNIVERSITY OF CALIFORNIA]

Linoleyl Alcohol: Preparation and Some Properties

BY OSMO TURPEINEN[1]

During the course of a recent work on the "essential unsaturated fatty acids"[2] it became desirable also to test the biological effectiveness of the alcohol corresponding to linoleic acid, linoleyl alcohol. It was found that this alcohol could be prepared easily from methyl linoleate by means of the reduction method of Bouveault and Blanc.[3] Since linoleyl alcohol evidently has never before been synthesized or isolated, it seems proper to report briefly on the preparation and some properties of this compound.

Preparation.—The starting material was methyl linoleate prepared from corn oil according to Rollet.[4] This ester was reduced with sodium in dry butanol. The procedure was principally the same as that suggested by Reid and co-workers[5] for the preparation of oleyl alcohol. The only points of difference were: (1) the methyl ester was used as starting material, and (2) the drying of the oil before the final distillation was done (in order to minimize the risk of oxidation) under reduced pressure in a large flask on a steam-bath. The final distillation was carried out under a pressure of approximately 1 mm., at which the main fraction boiled at 148–150°. The yields were comparatively good; 70–72% of the theoretical.

Properties.—Linoleyl alcohol is a colorless, oily liquid without a distinct odor or taste. Exposed to the air in a thin layer, it shows a tendency to "dry." Some of its characteristics were found to be as follows: specific gravity, d^{20}_{4} 0.8612; refractive index, n^{20}_{D} 1.4782; melting point, −5–−2°.

Halogen Addition.—The attempts to determine the iodine number of linoleyl alcohol resulted in only a partial addition of iodine. The Hanus method gave the following results: 152 (one hour), 160 (three hours), 158 (twenty-four hours), the theoretical value being 190.7.

For bromination 6.4 g. of linoleyl alcohol was dissolved in 20 cc. of carbon tetrachloride, the solution was cooled to 0°, and a 5% solution of bromine in the same solvent was added slowly. The reaction was rapid in the beginning, but languished later, and when about 80% of the theoretical amount of bromine had been added, the uptake of bromine was very slow. The bromination was stopped at this point without trying to force it farther. The solvent was evaporated, and the remainder, a yellow oil, was chilled at 0° overnight, at which it partially crystallized. The yield of the crystalline substance was, however, very small, only 0.95 g. After three recrystallizations from petroleum ether, the substance showed a constant melting point of 87–87,3°. The bromine content was: calculated for tetrabromooctadecanol ($C_{18}H_{34}OBr_4$), 54.56%, found, 54.2, 53.9%.

It is known that linoleic acid can be halogenated easily and completely. Since it would seem unlikely that the corresponding alcohol could show any considerably different behavior in this respect, the most natural conclusion to be drawn from the results reported above would be that the present preparation is contaminated with some less unsaturated impurities, which bring its mean degree of unsaturation *down to 80–85% of the theoretical.* That this conclusion is not, however, correct is shown by the following hydrogenation experiment.

Hydrogenation.—The reaction was carried out in Smith's micro hydrogenation apparatus.[6] The solvent was glacial

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(1) Rockefeller Foundation Fellow.

(2) The results of this work will be published in the *Journal of Nutrition.*

(3) L. Bouveault and G. Blanc, *Compt. rend.*, **136**, 1676 (1903).

(4) A. Rollet, *Z. physiol. Chem.*, **62**, 410 (1909).

(5) E. E. Reid, F. O. Cockerille, J. D. Meyer, W. M. Cox, Jr., and J. R. Ruhoff, *Org. Syntheses*, **15**, 51 (1935).

(6) J. H. C. Smith, *J. Biol. Chem.*, **96**, 35 (1932).