terials will eventually give us an exact description of mechanical failure in films and perhaps suggest the most fruitful experimental approaches toward solving this.

Swelling measurements are a likely approach to a study of the change in the extent of cross-linking in a film. Permeability studies also reflect the degree of cross-linking and the chemical composition of the film. In this particular field much of the work in the literature does not distinguish between true molecular transport through the film and gross diffusion of liquids or gases through mechanical defects in the film. Admittedly the probability of obtaining and maintaining a perfectly continuous film does depend on the polymer itself, the method of film preparation, the film thickness, the extent of degradation; and this is a problem worthy of study, but no useful purpose is served in confusing this with permeability. In the case of many polymers the hazards of film defects are such that a valid permeability experiment must demonstrate the absence of gross transfer.

Another whole area of properties which are affected by degradation are the electrical properties of a film. These have been studied most frequently by workers concerned with corrosion protection. Electrical measurements provide an excellent check on film continuity, and this is frequently valuable information. It is certainly true that the degradation of a film affects its electrical impedance, particularly in the presence of absorbed water, but the relation of these quantities to other chemical or physical data is beyond our present limitations of theory so that electrical measurements must remain an empirical though convenient method for following degradation.

In summary, the basic chemistry of linseed oil oxidation is well known, but the detailed quantitative description of the process in the film is uncertain. That this process leads to a film of complex chemical and mechanical properties has been demonstrated in theory and practice. Further progress in this field may suggest routes to more desirable films.

REFERENCES

1. Bolland, J. L., and Gee, G., Trans. Faraday Soc., *42*, 236 (1946).
2. Bolland, J. L., Quart. Rev., *3*, 1 (1949).
3. Farmer, E. H., J. Chem. Soc., *1943*, 541; *ibid.*, *1946*, 1022.
4. Miller, Caroline D., Ind. Eng. Chem., *50*, 125 (1958).
5. Shultz, A. R., J. Chem. Phys., *29*, 200 (1958).
6. Miller, Caroline D., Official Digest, June, 1958, p. 612.
7. Brandt, W. W., J. Phys. Chem., *63*, 1080 (1959).
8. Inoue, Y., J. Chem. Soc. Japan, *59*, 124 (1956).
9. Browne, F. L., J. Forest Products Research Soc., *4*, 391 (1954).
10. d'Ans, J., Farbe u. Lack., *61*, 54 (1955).
11. Miller, Caroline D., J. Polymer Sci., *24*, 311 (1957).

Chemical Intermediates and Derivatives from Unsaturated Oils and Acids

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THE SUBJECT for discussion is essentially that of the reactions of unsaturated fatty acids. Such fatty acids have two main points of reaction or reactive centers which are, of course, the carboxyl group and the unsaturated hydrocarbon chain having one or more carbon-to-carbon double bonds. Linoleic acid provides a good example of these reactive points.

Reactions involving the carboxyl group are many and varied and are used to provide a large group of commercially important products. These reactions include those of salt or soap formation, esterification, amidation, nitrile formation, amination, acid chloride formation, and many others. Even though this group of reactions would fall under the scope of this paper and numerous industrial organizations or enterprises are based on them, the only concern will be with the reactions of unsaturated fatty acids or their derivatives that occur at or are induced by the carbon-to-carbon double bonds present in the relatively long hydrocarbon chains. The reactions are, in general, fairly typical of those entered into by other nonterminal olefinic materials.

For the sake of simplicity, reactions of the double bonds or those induced by double bonds will be classified in the following four main categories:

a) the addition of chemical reagents across the double bond;
b) the reactions in which cleavage of the hydrocarbon chain at the double bond occurs to give lower molecular weight products;
c) the reactions in which isomerization of the double bond occurs; this may be geometric (oleic acid, which is the *cis* isomer, and elaidic acid, the *trans* isomer) or positional (oleic acid, which is Δ-9, and petroselenic acid, which is Δ-6) isomerization, or skeletal (oleic acid and 11-methyl-7-heptadecenoic acid) rearrangement, or a combination of these.
d) the reactions that do not take place at the double bond but do occur because they are induced by its proximity, such as reactions at carbons 8 and 11 in oleic acid and at carbons 8, 11, and 14 in linoleic acid.

In the case of linoleic acid carbon atom number 11 has the larger reaction potential because both double bonds have an influence on the reaction point.

An attempt will now be made to examine a number of processes, many of them practiced commercially today, and to show that they usually can be interpreted in the light of one or more of the above-mentioned type of reactions. Where possible, commercial utilization of the end products from such reactions or processes will be mentioned or described. It is believed that of special interest will be those processes and products which compete more or less directly with the corresponding ones in and of the conventional drying-oil industry.

Chemical Reactions of Unsaturated Oils and Their Fatty Acid Components

Addition Reactions. Chemical reactions in which two fragments add across a carbon-to-carbon double bond are quite common and numerous. Some of them are used for analytical purposes only, whereas others are used to prepare materials which are of considerable commercial significance. A partial list of such reactions would include the following where, for illustrative purposes only, oleic acid is used because of its relatively simple structure.

TABLE I

Addition Reactions of Unsaturated Fatty Acids

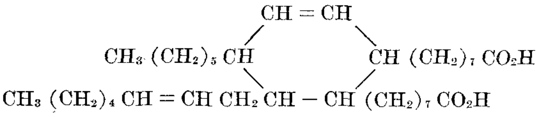
$CH_3(CH_2)_7CH = CH(CH_2)_7CO_2H$

Oleic Acid

Reagent	Product or purpose
H-H	Stearic acid
H-OH	Hydroxystearic acid
HO-OH	Dihydroxystearic acid
Cl-Cl	Dichlorostearic acid
NCS-SCN	Thiocyanogen number
Cl-I	Iodine value
Cl-OH	Chloro-hydroxystearic acid
H-HSO_4	Sulfated oleic acid
HO-$O_2C\ CH_3$	Acetoxy-hydroxystearic acid
HO-CH_2OH	Hydroxy-hydroxymethylstearic acid
H-Aromatic hydrocarbon	Arylstearic acid
H-SC_2H_5	Dialkyl sulfides
HCN-H_2SO_4	Formamido-stearic acid
N_2O_4	Dinitrostearic acid

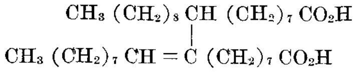
Table I represents a few examples of general addition reactions involving carbon-to-carbon double bonds and are considered separately from the following specific reactions of unsaturated fatty derivatives.

Reactions in which unsaturated fatty acids or their derivatives are polymerized are receiving increased interest as their utility becomes more and more established. Studies by Bradley (2), Cowan (4), Wheeler (13), and others have indicated that polyunsaturated fatty acids or certain derivatives of these fatty acids can be polymerized or "dimerized," by the use of heat. In such reactions these workers have indicated that normal 9,12-linoleic acid is first isomerized to a conjugated dienoic acid (either the 9,11- or 10,12-octadecadienoic acid), which then adds across the double bond of another unsaturated fatty acid (dienophile) as in a typical Diels-Alder reaction. The resulting product is then a dimeric acid containing a substituted cyclohexene ring.



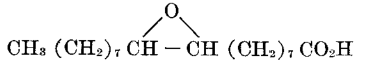
Dimer acid

In this over-all reaction it should be noted that the first step is an example of a Type c) or isomerization reaction, and the second step is an example of a Type a) or addition reaction. Polymerization of unsaturated fatty acids or their derivatives can also be carried out by the addition type of reactions in the presence of such catalysts as BF_3, $AlCl_3$, $ZnCl_2$, reactive clays, etc. It is believed that these reactions are examples of just the addition type of reaction and probably occur by some ionic mechanism. One relatively recent published structural representation of "dimerized" oleic acid was shown graphically as:



$$\begin{array}{l} CH_3(CH_2)_8\,CH\,(CH_2)_7CO_2H \quad (11) \\ \qquad\qquad\quad | \\ CH_3(CH_2)_7CH = C\,(CH_2)_7CO_2H \end{array}$$

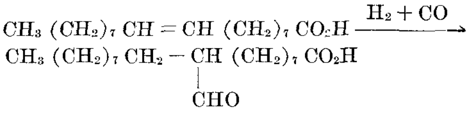
Another addition reaction of unsaturated fatty acid derivatives that is currently receiving quite a bit of attention is that of epoxidation. In this reaction an atom of oxygen is added across a carbon-to-carbon double bond to give an oxirane ring



The chemical reactant can be persulfuric acid, performic acid, peracetic acid, or hydrogen peroxide in the presence of ion exchange resins. The epoxystearic acid thus formed can be hydrogenated to hydroxystearic acid, hydrated to produce dihydroxystearic acid, or reacted with a number of other polar reagents to form substituted stearic acids. The principal interest in this epoxidation reaction however is in the production of vinyl resin stabilizers and plasticizers through the epoxidation of soybean oil, octyl oleate, and other ester derivatives of mono- and polyunsaturated acids.

One of the oldest additive reactions of unsaturated fatty acids is that of sulfurization. The chemistry of this reaction is not as well defined as that of some of the others mentioned, and products with widely varying sulfur contents can be prepared by heating the fatty material with elemental sulfur or certain sulfur-containing compounds.

More recently unsaturated fatty acids or esters have been used as the olefinic component in the "oxo" reaction (1). In this reaction, hydrogen and carbon monoxide are heated with the unsaturated fatty acid derivatives in the presence of a catalyst, which is usually a cobalt compound, in an autoclave under rather high pressures to yield a 19-carbon-atom saturated compound having both carboxyl and an aldehydic carbonyl groups:



$$\begin{array}{l} CH_3(CH_2)_7CH = CH(CH_2)_7CO_2H \xrightarrow{H_2 + CO} \\ CH_3(CH_2)_7CH_2 - CH(CH_2)_7CO_2H \\ \qquad\qquad\qquad\quad | \\ \qquad\qquad\qquad CHO \end{array}$$

This product can be readily reduced to the corresponding hydroxyacid or can be oxidized to the corresponding substituted alkyldibasic acid. In another version of the reaction the alkyldibasic acid can be prepared directly by heating oleic acid in the presence of carbon monoxide, hydrogen, water, and cobalt acetate.

A special type of reaction is that in which conjugated dienoic acids, such as those found in tung oil, oiticica oil, dehydrated castor oil, or in artificially conjugated linseed and soy oils are reacted with dienophiles, such as maleic anhydride, maleate and fumarate esters, acrylonitrile, crotonic acid, styrene, etc. The diene number which measures the amount of conjugated diene present in a drying oil generally utilizes this reaction with maleic anhydride as the dienophile. These reactions presumably all take place by a Diels-Alder mechanism and produce substituted cyclohexene derivatives.

Cleavage Reactions

The cleavage of unsaturated fatty acid derivatives at their carbon-to-carbon double bonds to form a variety of lower-molecular-weight chemicals has led to the development of a number of commercially important derivatives. Historically, unsaturated fatty acids have been cleaved at the double bond by oxidation processes. In fact, the earlier work that led to the structural identification of oleic, linoleic, linolenic, and other mono- and polyunsaturated fatty acids depended in part on the oxidation of the fatty acids, using potassium permanganate as the oxidant. The position of the carbon-to-carbon double bonds in the hydrocarbon chain was determined by identifying the acidic fragments recovered. For example, oleic acid yielded azelaic and pelargonic acid whereas petroselenic acid produced lauric and adipic acids. More recently however chromic acid, nitric acid, and ozone have been used commercially or semi-commercially for the production of mono- and dibasic acids by the disruptive oxidation of oleic acid alone or admixed with linoleic acid. The main products from these oxidation processes are azelaic and pelargonic acids.

The oxidation of oleic acid by use of air or gaseous oxygen in the presence of normal propyl alcohol under controlled conditions also reportedly produces good yields of azelaic and pelargonic acids. Two recent and novel patented processes for oxidizing oleic and linoleic acids to mono- and dibasic acids utilize both the addition and cleavage type of reactions. In the first, organic peracids are added across the double bonds of a mixture of oleic acid and linoleic acids to form acetoxy-hydroxy-fatty acids, which are then cleaved by oxidation by using nitric acid as the oxidant to form azelaic acid and a mixed monobasic acid. In the second (8), dihydroxystearic acid is formed by the *in situ* preparation and addition of persulfuric acid to oleic acid. The dihydroxystearic acid is then oxidatively cleaved by fusion with sodium hydroxide (7) to form the corresponding sodium salts of pelargonic and azelaic acids.

Other double-bond cleavages that involve a combination of isomerization and cleavage reactions are fairly well known. Ricinoleic acid or castor oil when heated with an alkali metal or alkaline-earth hydroxide first undergoes isomerization of the double bond, followed by an oxidative cleavage to form capryl alcohol and the corresponding salt of sebacic acid.

$$\underset{\text{Ricinoleic acid}}{CH_3(CH_2)_5CHOHCH_2CH=CH(CH_2)_7CO_2H} \xrightarrow{NaOH}$$

$$\underset{\text{Capryl alcohol}}{CH_3(CH_2)_5CHOHCH_3} + \underset{\text{Sodium sebacate}}{NaO_2C(CH_2)_8CO_2Na}$$

In the Varrentrapp reaction (9), oleic acid is heated with concentrated potassium hydroxide to give the salt of palmitic acid and potassium carbonate. This reaction is interpreted as first having the double bond in the 9,10-position shift to the 2,3-position. The oxidative cleavage then takes place at this point to give the forementioned products.

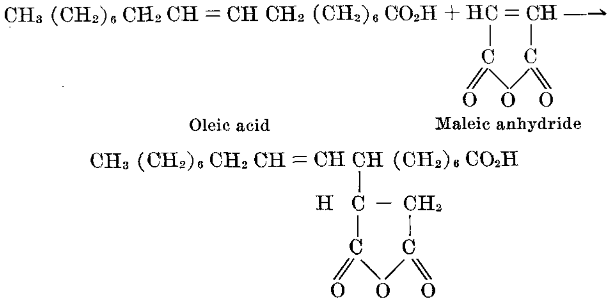
Another specific cleavage reaction takes place when unsaturated hydroxy acids, such as ricinoleic acid or its esters, are heated to pyrolytic conditions. Apparently isomerization precedes the pyrolytic cleavage, as is evidenced by the products that result, undecylenic acid and heptaldehyde.

Isomerization Reactions

Reactions involving the carbon-to-carbon double bond, in which the position of the double bond in the molecule or the spatial arrangement of other groups in relationship to the double bond is changed, are fairly common in fatty chemistry. These changes or isomerizations can be either positional or geometric in nature or can be accompanied by skeletal rearrangement, as shown previously. One of the more important isomerizations is the *cis-trans* type, of which the simplest example is the relationship between oleic and elaidic acids. Reagents such as nitrous acid, selenium, sulfur, iodine, phosphorus, and nickel are reported as catalysts for this type of reaction. Positional isomerization can be accomplished usually by heat alone, or catalysts may be employed. Various materials, especially nickel and iodine-containing compounds (5), have been recommended as catalysts for effecting conjugation of linoleic and linolenic acids as well as for the formation of "iso-oleic" acids. In addition, skeletal rearrangement of straight-chain unsaturated fatty acids to form branched-chain unsaturated fatty acids has been noted.

Reactions Induced by Double Bonds

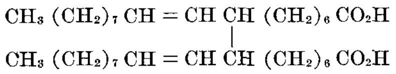
The fourth type of reaction is interesting and different from the others in that the carbon-to-carbon double bond itself does not enter the reaction but does provide the driving force for the reaction to take place. When unsaturated fatty acid derivatives are subjected to oxygen contact under prescribed conditions, hydroperoxides are formed. One recent publication (3) reports that good yields and high concentrations of oleic acid hydroperoxide are obtained by treating the acid or ester with oxygen in the presence of light and copper-free chlorophyll. The hydroperoxide groups (—OOH) almost invariably appear on the carbon atom which is adjacent or *alpha* to the double bond. The controlled action of sulfur trioxide on unsaturated fatty acid derivatives can result in the formation of sulfonic acid groups on these same *alpha* carbon atoms. When unsaturated fatty acids are reacted with maleic anhydride, adducts are formed which most probably result from the addition of a methylenic hydrogen of an *alpha* carbon atom of the fatty acid across the double bond of the maleic anhydride. The resulting product is an unsaturated substituted succinic anhydride.



Oleic acid Maleic anhydride

Adduct

Derivatives of fumaric, crotonic, and itaconic acids, etc., can be substituted for the maleic anhydride in this reaction. Another version of the Type d) reaction has been used by Wheeler (12), McCaleb (6), and Sutton (10) to produce dimeric or polymeric fatty acids from unsaturated fatty acid derivatives. In this process peroxides are used to remove hydrogen atoms from methylene groups which are *alpha* to the double bonds with the resulting formation of a single bond between carbon atoms of the two fatty chains as shown:



$$\begin{array}{l} CH_3(CH_2)_7CH=CH\,CH(CH_2)_6CO_2H \\ \qquad\qquad\qquad\qquad\quad | \\ CH_3(CH_2)_7CH=CH\,CH(CH_2)_6CO_2H \end{array}$$

Commercial Utilization of Products

The products resulting from the four types of chemical reactions of unsaturated fatty derivatives outlined above have found extensive interest in the market place. The volume of business is large, and the use pattern cuts a swath across nearly the entire spectrum of our economy.

The addition of hydrogen to double bonds of fatty derivatives is used widely to produce saturated structures. High-quality saturated fatty acids that are required for present-day soaps, detergents, and cosmetics usually owe in part their exceptional color, resistance to rancidity, and low iodine value to hydrogenation processes. The "hardening" or hydrogenation of fatty glycerides of both animal and vegetable origin produces many of the improved shortenings and margarines now available. Partially selective hydrogenation is used to remove polyunsaturated fatty acids from the unsaturated fatty acids used as soaps in synthetic rubber polymerization. Some of the latex or polymers produced are used in the so-called rubber-based paints that are proving so popular with the "do-it-yourself" painter. Sulfation of unsaturated fatty acids and their derivatives produces a variety of surface-active agents. Sulfated oleate esters have also been used in the textile industry as wetting agents for processing pre-shrunk cotton fabrics and in various detergent uses. Acetoxy-hydroxystearate esters have been recommended as vinyl resin plasticizers and for use in wax compositions. Halogenated fatty derivatives have been used as oil additives, especially in E. P. lubricant compositions.

During the past few years more and more interest has been shown in the use of epoxidized derivatives of unsaturated fatty acid derivatives as vinyl resin stabilizers and plasticizers. Epoxidized glycerides, such as soy oil, and epoxidized monohydric alcohol esters, such as octyl oleate, now are being sold in this market. At least three new such materials of undivulged composition have been put on the market during the past year. These materials act both as stabilizers and plasticizers. The oxirane ring apparently has the ability to react with hydrogen chloride that is given off slowly from polyvinyl chloride, thus preventing H-Cl from causing accelerated darkening and further deterioration of the resin articles or films. Also the epoxidized products have the proper carbon-to-oxygen ratio that enables them to be compatible with vinyl resins and to give the flexibility necessary for plasticization. Epoxidized fatty derivatives can also be used to modify the conventional epoxy resins.

Sulfurization of unsaturated fatty acid derivatives represents a fairly old art. Sulfurized sperm oil, glyceryl oleate, and other fatty esters have long been used as lubricant additives.

Perhaps however the products that compete most directly with drying oils are the polymerized fatty acids or products derived from them. Although these "dimer" acids have found use in oil additives and as corrosion-inhibitors for gasoline, turbine oils, and synthetic fluids as well as in a variety of miscellaneous uses, their main usage has been in the paint, resin, plastics, and coatings fields. Dimer acids have been incorporated as bodying agents in drying oils and as a flexibilizing agent in the baking type of alkyds. They have especially been recommended for use in epoxy resin modified oils and varnishes because they prevent surface dry and promote "through drying." Dimer acids or polymeric acids have been used as "curing" agents for liquid epoxy resins because of their ability to impart good electrical properties and resistance to mechanical and thermal shock to the resinous potting compounds. The dimer acids also are used with the casting or molding type of epoxy resins as well as with films of these materials, primarily because they impart flexibility to the finished product. In a few instances dimer acid has been built into the original epoxy compound to become part of a polymerizable monomer.

Dimer acids are also finding use in the polyurethane resin field where they are used mainly in the form of hydroxyl group terminated polyesters. Flexible urethane foams are prepared by reacting such a polyester with an aromatic di- or polyisocyanate in the presence of a small amount of water or blowing agent. These flexible cellular materials have found use as cushioning materials for upholstering, liners for crash pads in automobiles, rug underlays, clothing interliners, etc. Rigid cellular structures can also be formed that have found use in "in place" application for insulation. Iusulation of odd-shape cavities has been readily accomplished by injecting a small amount of the liquid resin mixture, which then fills the cavity with foam that sets to a rigidly closed cell structure. Solid urethane elastomers can be prepared by reacting the hydroxyl terminated polyester with a di-isocyanate in the absence of water. Such "urethane rubber" has found use in the manufacture of structural members in the automotive industry and other specialty uses. Urethane resin formulations containing dimer acid have also been used as wire-coating materials. In this use a liquid blocked prepolymer is used to coat the wire, and the coating is then set by heat.

Dimer acids are used as flexibilizing agents for polyester resin systems which use drying or semidrying oils, maleic anhydride, and styrene. These resins can be used in casting applications or in the lamination of glass fibers.

Probably the best developed use for dimer acids however has been in the polyamide resin fields. A whole series of products has been prepared from dimer acids and ethylene diamine and related polyalkylene polyamines. Some of the resins could possibly be referred to as polyamines having amide groupings. A very great volume of work has been done in this field, and the fruits of this work have provided products with wide utility. Polyamides from dimer acid and ethylene diamine have found use in paper coatings, as wood and metal primers, and in adhesives, sealants, and organic solders. Products from the reaction of dimer acid with diethylene triamine and other polyalkylene polyamines serve as curing agents or hardeners for epoxy resins, a process in which there is a novel aspect of using one resin to cure another. Systems of these resins have been used to form excellent adhesives, surface coatings with exceptional resistance to attack, and various hard and tough molded articles. Tools, dies, and machine parts have been advantageously made from such resin mixtures. It has been reported that a major automobile manufacturer is using an epoxy paint as primer for one line of his cars, and such polyamine type of curing agents can be used in this product. In another branch of the surface-coatings field, polyamide resins based on dimer acid form a basis for the manufacture of gelled or thixotropic paints.

The main chemicals obtained from cleavage reactions have been azelaic acid, capryl alcohol, heptaldehyde, pelargonic acid, sebacic acid, and undecylenic acid. Capryl alcohol and azelaic, pelargonic, and sebacic acids are used to manufacture a wide variety of monomeric, semi-resinous, and resinous plasticizers for vinyl resins. These products impart excellent low temperature, low volatility, and low migration properties to the finished compounded resin. This same group of acids has in the form of esters also provided the backbone for the production of the synthetic lubricants which are so necessary for the operation of jet aircraft at high altitudes.

Sebacic acid has been used very extensively in the production of 6-10 nylon which is used for bristles and other monofilament applications. Pelargonic acid has been used in a wide range of industries including the fields of baking alkyds, ore flotation, pharmaceuticals, and perfumery. Undecylenic acid has been used to manufacture a polyamide called Rilsan and currently is used rather widely in the drug trade as a fungistat and in perfumery to form peach aldehyde, which is in reality undecalactone. Heptaldehyde is used primarily in the perfume industry.

Isomerization reactions, although occurring quite widely in chemical reactions of unsaturated fatty acid derivatives, have not led to a very large number of commercial products. Conjugated dienoic fatty acids have been used in the paint field to a certain extent especially where more rapid dry or reaction with styrene, cyclopentadiene, etc., are desired. Elaidinization of certain glycerides has produced substitutes for the very expensive cocoa butter. Other *trans*-isomers of fatty acids have been reported to impart unique and improved properties to soaps made from them. Skeletal rearrangement of unsaturated fatty acids having an 18-carbon atom straight-chain has produced a branched-chain unsaturated fatty acid (of the same carbon content) that, when hydrogenated, gives a liquid rather than a solid product.

Products from the reactions of unsaturated fatty derivatives that are induced by double bonds have not to date found extensive application. Polybasic acids or their anhydrides, produced from oleic or linoleic acids and maleic anhydride, may find use as epoxy resin curing-agents. The ester form of such products has been recommended as a vinyl resin plasticizer. Hydroperoxides of fatty acids or esters have been recommended as polymerization catalysts for certain resin systems.

REFERENCES

1. Alm, R. M., and Shepard, J. W., U.S. Patent 2,891,084 (April 30, 1956) to Standard Oil of Indiana.
2. Bradley, T. F., and Johnson, W. B., Ind. Eng. Chem., *32*, 802 (1940).
3. Carter, R. O. Jr. U.S. Patent 2,727,857 (December 20, 1955) to Procter and Gamble Company.
4. Cowan, J. C., and Falkenburg, L. B., Oil and Soap, *20*, 153 (1943).
5. Cowan, J. C., Ind. Eng. Chem., *41*, 294–304 (1949).
6. Harrison, S. A., and McCaleb, K. E., U.S. Patent 2,731,481 (January 17, 1956) to General Mills Inc.
7. Logan, R. L., U.S. Patent 2,625,558 (January 13, 1953) to Kessler Chemcial Company.
8. Logan, R. L., U.S. Pat. 2,688,031 (April 30, 1954) to Kessler Chemical Company.
9. Ralston, A. W., "Fatty Acids and Their Derivatives," New York, Wiley, 1948, p. 474.
10. Sutton, D. S., J. Am. Oil Chemists' Soc., *30*, 53–56 (1953).
11. Topchiev, A. V., and Zavgoradnii, S. V., and Paushkin Ya. M., "Boron Fluoride," New York, Pergamon Press, 1959, p. 190.
12. Wheeler, D. H., and Harrison, S. A., Minn. Chemist, *4*, 17 (1952), No. 5.
13. Wheeler, D. H., J. Am. Oil Chemists' Soc., *27*, 440 (1950).

The Economics of Drying Oils

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DURING THE COURSE of this series you have heard a great deal of expert information about factory and laboratory handling of drying oils. That is as it should be for this is a technical group, gathered for a technical purpose. Yet on reflection we must realize that at no stage, from planting of crop to consumption in end-use, can drying oils be divorced from economics. For economics dictates much of the pattern of production, distribution, and consumption and controls much of the research. Despite these profound effects the economics of this field has enjoyed remarkably little investigation. Applied economics, which concerns us here, involves the study of business alternatives, determinants, and decisions. It is always easier to study the last of these items as decisions, for better or worse, are matters of record. Past decisions are reflected in historical statistics so let us take a look at them.

The History. The most striking economic facts in connection with drying oils are, first, the failure of usage to expand in what we usually consider to be a dynamically growing economy, and second, the steady decline in the use of oils as a percentage of a gallon of paint (Tables I and II). The failure of paint and varnish sales to expand much despite the heavy housing construction of recent years and despite relative consumer prosperity can seemingly only be explained as a merchandising problem. The loss of position of drying oils is more familiar to all of you. The first big loss came during the oil-short days of World War II when many firms were forced to re-examine classical theories of pigment-to-binder ratios. The post-World War II period saw the introduction of styrene-butadiene-latex emulsion paints. New oil products and better methods of processing familiar oils were developed under pressure of latex emulsion competition. Some of these oil-type of products, notably alkyds, reduce oil consumption per gallon.

Consumers have demanded, and have gotten, products more suited to the do-it-yourself requirements of the average home-owner. In large measure these

TABLE I
Production of Paint and Varnish 1948–1958

Year	Total		Containing drying oils	
	Million gallons	Oil used per gallon	Million gallons	Oils used per gallon
1949	485	1.4	349	1.9
1950	599	1.3	432	1.8
1951	542	1.4	389	1.9
1952	536	1.3	374	1.8
1953	556	1.3	381	2.0
1954	545	1.3	375	1.8
1955	599	1.1	371	1.8
1956	587	1.2	371	1.9
1957	586	1.1	353	1.8
1958 (prel.)	598	1.0	367	1.6

Source: U.S.D.A. FOS 195, March 1959, p. 26.