

THE FATS AND OILS
A GENERAL VIEW

G. H. ALSBERG AND A. E. TAYLOR

FATS AND OILS STUDIES
No. 11 FEBRUARY 1928

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THE FATS AND OILS

A General View

A simple, elementary, and nontechnical exposition of the production, the technology, and the interrelations of the various fats and oils. Designed to present in readily intelligible form the information desirable for an understanding of the fats and oils trade as it affects agriculture and industry

By

CARL L. ALSBERG

and

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Directors, Food Research Institute

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THE FATS AND OILS: A GENERAL VIEW

FATS AND OILS STUDIES
OF THE
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- No. 1. *The Fats and Oils: A General View*
No. 2. *Copra and Coconut Oil*
No. 3. *Inedible Animal Fats*
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No. 1 ' ' ' ' **February, 1928**

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FOOD RESEARCH INSTITUTE
STANFORD UNIVERSITY, CALIFORNIA

The Food Research Institute was established at Stanford University in 1921 jointly by the Carnegie Corporation of New York and the Trustees of the Leland Stanford Junior University, for research in the production, distribution, and consumption of food.

DIRECTORS

CARL LUCAS ALSBERG, JOSEPH STANCLIFFE DAVIS,
ALONZO ENGLEBERT TAYLOR

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DIRECTORS' PREFACE

War-time experience demonstrated the basic importance of the fats and oils for food, feed, and raw material for industry. The growth of international trade and increasing substitution of one fat for another in response to changes in consumers' preferences and manufacturers' technique have given rise to serious problems of public policy, especially with respect to food laws and tariff restrictions. Yet the literature dealing with fats and oils is notably deficient in its economic and statistical aspects, largely because these materials are so diverse in origin and use and are yet to a high degree interchangeable.

These considerations have led the Food Research Institute to undertake intensive investigations in this field and to begin publication of a series of *Fats and Oils Studies*. Emphasis is placed upon the economic phases of the trade, and upon the food rather than the industrial uses, though due consideration is given to relevant scientific knowledge. The principal objective is to develop an increased understanding out of which sound views upon questions of public policy and business practice may be evolved.

Each number of the series constitutes an independent consideration of a selected topic; but so intimate is the relationship among the various fats and oils that each study must be regarded as an integral part of the series.

A fairly intimate knowledge of the origins, manner of production, and technical uses of the several important classes of fats and oils is a prerequisite for study of their economic significance. It is therefore rational to present in this, the first of the series, a simple, elementary, and, so far as possible, non-technical exposition of the production, the technology, and the interrelations of the various

fats and oils, which may serve as a background for the more specialized studies that are to follow. The purpose has been to prepare the reader, who is assumed to be without training in chemistry, chemical engineering, or biology, for intelligent reading of studies of particular fats and oils in which the emphasis is primarily economic even though some reference may be made to technical matters of production, manufacture, and consumption.

In the present treatise, little that is new is presented. Nearly all of the material could be found by diligent search in one or another of the many handbooks dealing with the chemistry of foodstuffs, with the chemistry of fats and oils, with the technology of the industries employing fats and oils as their raw materials, with the nutrition of man and domesticated animals, and with governmental supervision over the food trades. In no one place, however, does the information desirable for an understanding of the fat and oil trade as it affects agriculture and industry seem to have been collected in a form so simple as to be intelligible to those without technical training. To supply such a presentation is the object of this initial study.

Studies contemplated for the immediate future will deal with copra and coconut oil, inedible animal fats, the McNary-Haugen plan as applied to corn and hogs, and the history of the lard-compound industry.

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STANFORD UNIVERSITY, CALIFORNIA
February 1928

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THE FATS AND OILS: A GENERAL VIEW

I

NATURE AND SOURCES OF FATS AND OILS

CHEMICAL AND PHYSICAL CHARACTERISTICS

The present study deals only with such oils and fats as are capable of serving as foodstuffs, even though in practice they are not put to such use. The common chemical characteristic of such oils and fats is that they may be decomposed into glycerin and one or more acids of the class known to chemists as fatty acids.¹ The common physical properties of such oils and fats are that they float on water but are not soluble in it; they are greasy to the touch, and have lubricating properties; they are not readily volatile; and may be burned without leaving any residue, i.e., ash. No other class of substances has the chemical properties of the fats and oils; but many possess similar physical ones, e.g., mineral oils, earth-wax (ozocerite), paraffin, animal waxes like spermaceti or beeswax, vegetable waxes like carnauba or candelilla wax, volatile or essential vegetable oils like the oils of thyme, of cloves, of cedar, and attar of roses. None of these substances furnishes both glycerin and fatty acids; none of them has nutritive value; none of them will be considered further in this treatise.

Fats and oils, then, in the restricted meaning in which these two words are used hereafter, are substances which

¹ Chemists designate as acids a class of substances which have an acid or sour taste; contain the element hydrogen; and act upon metals, hydrogen being evolved and its place being taken by the metal. The compound thus formed with the metal is known as a salt.

consist always of chemical combinations of glycerin with certain fatty acids, and which may serve as foods.

The distinction between a fat and an oil is purely an accidental one depending upon the environment in which the substance happens to be placed. If the substance is solid at ordinary temperatures, it is termed a fat; if fluid, an oil. This is merely a distinction of convenience, since all oils are solidified at lower temperatures and all fats melted at higher temperatures. Obviously, the dividing line that holds for a cool climate would not hold for a hot one. In each climate, however, the distinction is of importance in industrial and in culinary uses; it has also some importance in nutrition, since fats are somewhat less digestible than oils. In this study "fat" is often used indiscriminately for a solid or a liquid substance of the class here under consideration.

ANIMAL AND VEGETABLE SOURCES

Animal fats and oils are derived both from terrestrial and marine animals. Marine fats include liver oils, blubber oils, and fish oils. In addition, from certain marine animals waxes are obtained, e.g., spermaceti, which, because it is a wax and not a fat, need not be considered here. The different types of marine fats, which in practice are often mixed, have been of great importance in the past and still possess considerable significance. Some of these serve special purposes, such as codliver oil; others are used to some extent as foodstuffs; but for the most part they serve industrial uses.

With two important exceptions animal fats are obtained from carcasses. These two exceptions are butter and the fat of the yolks of eggs. Carcass fat is found in different locations. There is a good deal of it in the visceral cavities and in and around the viscera. More or less of it occurs in the muscles, in the connective tissue, under the skin, and in the bones. The proportions found in the

different parts of the body vary from species to species and in any given species with the age of the individual animal and its condition. The fats from the different parts and organs of a given animal differ somewhat in their properties. As a rule, the fat from the interior of the animal is somewhat firmer than the fat from near the body surface, i.e., it melts at a somewhat higher temperature. Furthermore, under certain conditions the feed of the animal affects the physical properties of the carcass fat more or less. Animals fattened upon a diet containing much oil—for example, peanuts—tend to produce softer carcass fats than animals of the same species fattened upon a diet containing relatively little oil—for example, corn (maize). Animals form fairly specific fats from starches but deposit in their tissues unchanged such portion of the fats and oils of the ration as is not promptly oxidized.

Vegetable fats and oils are found in greatest abundance in fruits and seeds. While fats and oils do occur in the roots, stalks, branches, and leaves of plants, they are rarely present in these organs in quantities large enough for commercial purposes. In some seeds and fruits, however, the fat content is great—in several cases as high as 35 per cent; in dried coconuts 65 per cent—and these are the commercial sources of vegetable fats. In some seeds the fat is practically confined to the germ or embryo; this is the fact in most of the cereals.¹ The olive contains a large amount of fat in the pulp surrounding the kernel and only a smaller amount in the kernel itself, while in the oil palm both the pulp and the kernel contain large amounts. The fat from the pulp may have characteristics quite different from those of the fat in the kernel.

¹ The germ or embryo is that part of the seed which gives rise to the plant when the seed germinates. It is usually only a small part of the seed. The remainder of the seed consists mainly of reserve food material with the help of which the embryo grows into the plantlet which, as it develops roots, is enabled to draw its nourishment from the soil.

EDIBLE AND INEDIBLE FATS

In commerce a distinction is commonly made between "edible" and "inedible" fats, based either upon external characteristics, such as unattractive color, taste, or odor, or upon sentimental considerations, such as revolting origin (from garbage, for example), decomposition, or the possibility of contamination with a poisonous substance or with the germs of disease. The distinction between edible and inedible fats is nevertheless a purely practical one, for with modern methods nearly all fats can be refined or modified to the point of physiological edibility. That the distinction exists at all is because it is either unprofitable to convert inedible into edible fat to a greater extent than is done or else because such conversion is not permitted for sanitary reasons.

Sanitary considerations are a more important factor deterring the transformation of inedible into edible fats in the case of animal than in the case of vegetable products, for animal fats may be treated as inedible, even if they are not repulsive to the senses, because their origin is revolting. This is the case when they are obtained from animals that have died otherwise than by slaughter, i.e., from disease, old age, or accident. Such fats are not permitted by health authorities to be used for food purposes because of the danger of transmitting disease, though in former times some fat of this sort was unquestionably so used. Because of the danger of disease transmission, fat from animals killed by slaughter is not permitted to be used for food if inspection of the carcass shows that the animals were diseased. In most countries inspections have been established in slaughterhouses to protect the consumer from this danger. The degree and effectiveness of such inspections vary in different sections and in different countries. In the United States, food fats remain subject to the provisions of federal and local food laws after they are shipped out of the inspected slaughterhouse. They

may, therefore, if officials deem it necessary, again be inspected at any time on their way to the consumer.

So far as is known to date, there is little or no danger of the transmission of diseases of plants to man. Therefore, governments have not thought it necessary to supervise the production of vegetable fats in the same rigid manner in which fat production from animal carcasses is controlled. The only sanitary control over vegetable oils that exists, aside from the very special control applied to the manufacture of margarin, is the general control exercised by the several food laws over vegetable oils in common with all other foodstuffs. This form of control concerns itself principally with adulteration, with decomposition (rancidity), and with various types of misbranding. Vegetable oils, in common with nearly all other foodstuffs, may transmit disease if handled by infected persons. Such occurrences are extremely rare and of a type not at present controllable by food officials.

DRYING AND NON-DRYING OILS

In commerce the distinction between edible and inedible fats is not the only one that is made. A different but equally important distinction is drawn between the drying and the non-drying oils. The two kinds of distinction are not comparable, for both non-drying and drying oils may be either edible or inedible. Thus in Europe linseed oil (a typical drying oil) is used for food, whereas in America it is not now so used—for one reason because it is too expensive as compared with non-drying oils which are readily available in abundance.

Drying oils absorb oxygen from the air and are thereby converted into plastic, elastic, resin-like substances. Hence, when exposed in a thin layer, as in painting, they form a tough, elastic, waterproof film which adheres tightly to the painted surface and protects it from the weather. The two chief drying oils are linseed oil and

tung (chinawood) oil, which find wide use in the manufacture of paints, varnishes, artificial rubber, linoleums, and other coverings.

The non-drying oils find a wide variety of industrial uses: they enter into soaps and cleansers, cosmetics, lubricants, leather dressings, and candles. They are used in the processes of wool manufacture, especially carding; they are employed in making tin plate and in foundry work. Fats and oils, whether edible or inedible, drying or non-drying, have still other industrial uses. They were the primitive illuminants and are still so used in a relatively slight degree. Some of the industrial uses of the fats and oils depend upon their physical properties, others upon their chemical character, to which detailed reference will be made later.

Between the drying oils and the non-drying oils is a group of oils which, while they possess the property of absorbing oxygen, do not do so sufficiently to qualify them as drying oils. They are changed more or less when exposed to the atmosphere, but not as completely as linseed, tung, and certain other drying oils. They are often termed semi-drying oils. All gradations are found between completely drying oils and completely non-drying oils. Soy bean oil and corn oil are examples of semi-drying oils. When exposed to the atmosphere in a thin layer they thicken but do not form a hard, dry film. The film remains sticky and somewhat runny—tacky is the word often used. Under some circumstances appropriate amounts of semi-drying oils are mixed with full-drying oils to make paints of cheaper grades.

DETERIORATION OF FATS AND OILS

Fats and oils are quite unstable substances. When stored for any considerable length of time, especially when the temperature is high and the air has free access to them, they deteriorate and spoil. In this respect different

fats differ markedly. Some spoil very much more rapidly than others. Among the various fats, spoilage takes the form of rancidity. The fat acquires a peculiarly disagreeable odor and flavor. A vast amount of scientific research has been carried on to determine the cause and nature of rancidity, but investigators are far from agreement on the subject. For present purposes it is sufficient to point out that spoilage of a fat, usually identical with rancidity, is accompanied by partial splitting of the fat into glycerin and fatty acids. The glycerin disappears, or at any rate is unobjectionable, but the fatty acids remain dissolved in the fat, give it an acid reaction, and contribute to its objectionable rancid flavor.

The rancidity of a given parcel of fat is not necessarily the result of long storage under unfavorable conditions. The fat may have been spoiled and rancid from the moment of its production. This will inevitably be true when the materials from which it was produced have undergone decomposition. Thus the fat obtained from putrefying carcasses will be rancid and so will the oil expressed from fermented cottonseed. In other words, to obtain a sound and sweet fat, the raw material must be sound and sweet; it must be worked up speedily before it has had time to decompose; and this must be done under clean and sanitary conditions. The fat thus obtained must be stored under favorable conditions and its consumption cannot be too long delayed. These conditions it is difficult to obtain in many of the less civilized portions of the world, especially in the tropics, where many fat- and oil-yielding raw materials are produced. Hence fats and oils made at the source of the raw materials may be less sound than those produced at or near the place of consumption.

The fact that so great a proportion of the fat supply, especially vegetable oils, is or becomes rancid and decomposed, necessitates refining, decolorizing, and deodorizing. Certain oils—for example, cottonseed oil—require

refining even when they are not decomposed, because they contain certain impurities and are of dark color. The act of refining is not merely an item of expense, but in the case of decomposed fats it involves the removal of the fatty acid contaminating the fat or oil. The effect is that the yield of refined oil is less than the crude oil with which the operation was begun. This disappearance of material is known in the trade as the "refining loss." Hence the trade in fats, oils, and greases specifies the amount of free fatty acids permissible in them. If the amount exceeds specifications, price adjustments are commonly demanded and conceded. If the refining loss is too heavy to make refining economical, the fat is commonly consigned to the soap kettle. The past history of a fat—whether or not it was ever decomposed—in some way not clearly understood, affects its keeping quality after refining. Such fats require especially great care and skill in refining, deodorizing, and decolorizing to insure reasonable keeping qualities. It may not be profitable to refine a fat even though the refining loss be only moderate.

II

PROPERTIES OF FATS AND OILS

For an understanding of the place of fats and oils in the diet and in the arts, some elementary knowledge of their chemical and physical properties is essential. It is the object of this section to present the minimum of such necessary information in the simplest way practicable.¹

CHEMICAL COMPOSITION

As already stated, fats may be decomposed into glycerin and fatty acids. This manner of decomposition takes place only in the presence of moisture. For each molecule² of glycerin set free there are set free three molecules of fatty acid. In the process three molecules of water are taken up, partly to help re-form the glycerin and partly to help re-form the fatty acids. Conversely (in the laboratory) the fat may be reconstituted from glycerin and fatty acid, in which event three molecules of water are set free for each molecule of fat synthesized.

The process of splitting a substance whereby water is taken up is known to chemists as hydrolysis, a word which is merely Greek for cleavage by water. The process is often termed saponification, since it was first observed to take place in the manufacture of soap. The term saponification (instead of the more exact term hydrolysis) is, however, applied indiscriminately and inappropriately to any chemical change of this nature, whether or not soap is formed. Nowadays in industry fats are very often con-

¹ For complete treatment of the chemistry of fats and oils see J. Lewkowitsch, *Chemical Technology and Analysis of Oils, Fats, and Waxes* (London, Macmillan, 1922, 3 vols., 6th edition).

² A molecule is the smallest particle of a substance that can exist and still exhibit the properties of that substance.

verted into glycerin and fatty acids—that is, hydrolyzed—without the formation of any soap whatever. A soap is merely the combination of a fatty acid with a metal, i.e., it is a salt. The commonest soaps are the fatty-acid salts of sodium¹ and potassium.² Hard soaps are sodium salts; soft soaps, potassium salts. The fatty-acid salts of ammonium are also sometimes used for cleansing. Only a few other soaps are of practical importance, for example lead soaps which are used in medicinal plasters, zinc soaps which are used in ointments, and aluminum soaps which are used in waterproofing. Very few of the salts of fatty acids have the properties of common soap. Most of them are but slightly soluble in water, and therefore do not yield suds and have little or no detergent (i.e., cleansing) action. All are nevertheless termed soaps by chemists.

TRIGLYCERIDS AND FATTY ACIDS

As above stated, fats may be split into glycerin and fatty acids, the resulting mixture containing three molecules of fatty acid for each molecule of glycerin. Because of this proportion of acid to glycerin, the chemical compounds found in the fat before it was split are known to chemists as triglycerids. Since there are a number of different fatty acids that occur in natural fats, a great many different triglycerids are encountered in nature. These are named according to the fatty acid or acids they contain. Thus triolein is the triglycerid of oleic acid, tripalmitin that of palmitic acid, tristearin that of stearic acid, while monopalmitin-distearin contains, as the name indicates, one molecule of palmitic and two of stearic acid.

While a large variety of fatty acids is found in natural fats and oils, only a few of them are of outstanding com-

¹ Sodium is a soft, white metal obtained from common salt, sodium chlorid.

² Potassium is also a soft, white metal obtained from wood ashes or from certain minerals found in Germany, Alsace, and elsewhere. Both sodium and potassium oxidize with great rapidity when exposed to the air, and hence are never found in nature except in the form of their compounds.

mercial importance. These are myristic acid, lauric acid, palmitic acid, stearic acid, oleic acid, linolic acid, and lino-
lenic acid. Though the number of triglycerids encountered
in nature is great, the triglycerids of these seven acids¹
make up the great bulk of the natural fats and oils. Fats
and oils are practically always mixtures of triglycerids in
varying proportions. In some fats one triglycerid predomi-
nates, in others another, and in still others several are pres-
ent in material amounts. Apparently no natural fat or oil
consists solely of a single triglycerid. The properties of dif-
ferent fats and oils depend upon the characteristics of the
triglycerids of which they are mixtures and upon the pro-
portions of these triglycerids to one another.² The fats of
different species of animals and plants vary widely. In-
deed, the fat from a given natural source, say a given

¹ The formulas of these acids (disregarding isomers) are as follows:

Acid	Elementary Formula	Constitutional Formula
Lauric	$C_{12}H_{24}O_2$	$CH_3(CH_2)_{10}COOH$
Myristic	$C_{14}H_{28}O_2$	$CH_3(CH_2)_{12}COOH$
Palmitic	$C_{16}H_{32}O_2$	$CH_3(CH_2)_{14}COOH$
Stearic	$C_{18}H_{36}O_2$	$CH_3(CH_2)_{16}COOH$
Oleic	$C_{18}H_{34}O_2$	$CH_3(CH_2)_{14}(CH)_2COOH$
Linolic	$C_{18}H_{32}O_2$	$CH_3(CH_2)_{12}(CH)_4COOH$
Linolenic	$C_{18}H_{30}O_2$	$CH_3(CH_2)_{10}(CH)_6COOH$

² E. T. Webb, "Oils and Fats in Soap Manufacture," *Soap Gazette and Per-
fumer*, October 1, 1926, XXVIII, 302, gives the following percentages of the more
important fatty acids in commonly used fats and oils. Other investigators may
find somewhat different proportions, but in general these are representative:

Fat or oil	Lauric	Myristic	Pal- mitic	Stearic	Oleic	Lino- lic	Lino- lenic
Coconut	45	20	5	3	6	...	...
Palm kernel	55	12	6	4	10	...	...
Tallow (beef)	2	29.0	24.5	44.5	...	...
Tallow (mutton)	2	27.2	25.0	43.1	2.7	...
Lard	24.6	15.0	50.4	10.0	...
Olive	14.6	...	75.4	10.0	...
Arachis (peanut)	8.5	6.00	51.6	26.0	...
Cottonseed	23.4	...	31.6	45.0	...
Malze	6.0	2.0	44.0	48.0	...
Linseed	3	6.0	...	...	74.0	17.0
Soy bean.....	11.0	2.0	20.0	64.0	3.0

species of animal or plant, may contain the same triglycerids in slightly different proportions, depending upon the conditions of the environment prevailing while the fat was being formed. It was pointed out in the preceding section that the properties of the fat of an animal vary somewhat with the diet and also with the tissue from which it is obtained. It was also pointed out that a fruit may yield two fats of different properties, one from the pulp and one from the kernel. In the case of plants the fat may also vary with the cultural variety of the plant and with the climatic and soil conditions under which the plant was grown. Thus the linseed oils from Argentina, India, Russia, and the United States have slightly different chemical and physical properties.

Fats and oils being mere mechanical mixtures of triglycerids, it is possible in many cases to separate them more or less completely into their component triglycerids by simple mechanical means, chilling and pressure. Such processes have considerable commercial importance, as, for example, the separation of lard into lard oil and lard stearin or of beef tallow into oleo oil and oleostearin (see p. 34).

For the details of the chemical nature of the fatty acids, the reader is referred to the texts on organic chemistry.¹ Here it is sufficient to point out that they all possess the characteristic property of acids in general, viz., to combine with bases to form salts. These salts, as was pointed out above, are known as soaps whether or not they have detergent action. Moreover, all fatty acids contain carbon, hydrogen, and a small proportion of oxygen. They differ from one another in the number of carbon atoms in each molecule, in the proportion of carbon to oxygen their molecules contain, and also in the proportion of carbon to hydrogen. Upon these ratios the physical

¹ A. Hollemann (trans. H. C. Cooper), *A Textbook of Inorganic Chemistry* (New York, Wiley, 1904).

and chemical properties of the acids and of their triglycerids very largely depend.

SATURATED AND UNSATURATED FATTY ACIDS

It would carry us too far to discuss these relationships in detail here. For present purposes it is sufficient to limit consideration to one of the aspects of the carbon-hydrogen ratio of the fatty acids. When the fatty-acid molecule contains the maximum of hydrogen possible, the acid is said to be a saturated fatty acid. It is saturated with respect to hydrogen. Myristic, lauric, palmitic, and stearic acids are such saturated acids. They are solids at ordinary temperatures. When, however, the fatty-acid molecule does not contain the maximum amount of hydrogen possible, the acid is said to be an unsaturated fatty acid. It is unsaturated with respect to hydrogen. Such unsaturated acids are oleic, linolic, and linolenic acids. They are liquids at ordinary temperatures. By chemical means these acids may be made to take up, i.e., combine with, hydrogen. This process is known as hydrogenation. It converts a more unsaturated fatty acid into a less unsaturated one, or, if the hydrogenation is carried to completion, into a saturated fatty acid. Thus by hydrogenation oleic acid is converted into stearic acid. Linolic acid when hydrogenated can be made to take up twice as much hydrogen as oleic acid, and linolenic acid three times as much. Linolic acid is, therefore, a more highly unsaturated acid than oleic, while linolenic acid is more highly unsaturated than linolic.

Unsaturated fatty acids can be made to combine with other substances instead of with hydrogen. For example, they may be made to take up iodine or oxygen. Acids of a low degree of unsaturation, such as oleic acid, do not combine with oxygen with any great degree of avidity, but acids of a greater degree of unsaturation, such as

linolic or linolenic, combine with it very readily; they do so merely upon exposure to the air.

The properties of the fatty acids just described, which depend upon their degree of saturation or unsaturation with respect to hydrogen, are retained by them when they are in combination with glycerin as triglycerids. Hence the different fats are also more or less saturated, according as they contain greater or lesser proportions of the triglycerids of saturated or unsaturated fatty acids. When fats contain large amounts of trilinolin and trilinolenin, these absorb oxygen avidly. It is upon the presence, then, of these unsaturated triglycerids that the properties of drying oils described in the preceding chapter depend. Resin-like films are formed by them when oxygen is absorbed because the oxidation products of these unsaturated triglycerids are relatively insoluble solids. Upon this reaction, as already pointed out, is based the behavior of paints.

MEASURES OF UNSATURATION

It is obvious, then, that it is important for industrial users of fats to know the degree of unsaturation of a given parcel of fat. This might be ascertained by determining the amount of hydrogen required to convert it into a saturated fat. In practice this is a complicated procedure and so simpler methods are resorted to. The simplest of these is the determination of the amount of iodine that can be made to combine with the fat. The percentage by weight of iodine absorbed by the fat in the natural state is known as the "iodine number." It is an index to the degree of unsaturation of the fat. The iodine number¹ of the commoner fats are given in Table 1. Examination of the table shows that the fats with the highest iodine numbers are the drying

¹ For details concerning this and other methods of testing fats, see "Standard Methods for the Sampling and Analysis of Commercial Fats and Oils," *Industrial and Engineering Chemistry*, December 1926, XVIII, 1346.

oils *par excellence*, linseed and tung oil, with which must also be classified menhaden fish oil.

TABLE 1.—IODIN NUMBERS OF COMMON FATS*

Fat or Oil	Iodin number
Linseed oil	173 -201
Tung Oil	170.6
Menhaden oil	139 -173
Whale oil	121 -146.6
Soy bean oil	137 -143
Sunflower oil	119 -135
Corn oil	111 -130
Cottonseed oil	108 -110
Sesame oil	103 -108
Rapeseed oil	94 -102
Peanut oil (arachis)	83 -100
Olive oil	79 - 88
Horse oil	71 - 86
Lard	46 - 70
Palm oil	51.5- 57
Milk fat	26 - 50
Beef tallow	38 - 46
Mutton tallow	35 - 46
Cacao butter	32 - 41
Palm kernel oil	13 - 17
Coconut oil	8 - 10

* Data from J. Lewkowitsch, *Chemical Technology and Analysis of Oils, Fats, and Waxes*, pp. 419-24.

OTHER USEFUL TESTS

There are, of course, many other tests besides iodine absorption that are used in commercial practice. This is not the place to discuss them in detail. A few of them, however, deserve mention in passing.

The iodine number of a fat tells us the degree of unsaturation of a fat. It does not tell us whether the unsaturation is the result of the presence of triolein only, of trilinolin only, of trilinolenin only, or of a mixture of the three. As the drying qualities depend mainly upon trilinolin and trilinolenin, paint manufacturers are not always

satisfied with the determination of the iodine number. In such cases they determine the amount of oxygen the oil tested will absorb under standard conditions. As the absorption of oxygen is mainly by the trilinolin and trilinolenin, this test is used to supplement the iodine number.

In the preceding section it was stated that fats often become decomposed and rancid and that they then contain free fatty acids,—i.e., acid uncombined with glycerin. It was also pointed out that it is important to the industrial user to know the amount of free fatty acid present, since this determines in large measure the refining loss. The amount of free fatty acid is estimated by determining the quantity of alkali that must be added to the fat to render it quite neutral. Sometimes, in addition to estimating the free fatty acid in this way, the actual loss in refining is also determined. This is done by warming a known amount of the fat with strong aqueous caustic soda¹ solution, which converts the free fatty acid into soap. This soap is then removed and the amount of fat remaining is then determined. The loss is estimated by subtracting this amount from the amount of fat originally taken for the test. The amount and strength of caustic soda solution, the temperature, and the length of treatment are so chosen that only the free fatty acid and other impurities present in the oil are removed and but little, if any, saponification of neutral fat takes place.²

As also pointed out in the first section, many crude fats as they come upon the market are either naturally deeply colored or have become so through decomposition. Since for many uses such fats must be decolorized, the ease with which this may be done is an important factor in determining their commercial value. Hence one of the

¹ Caustic soda is a compound of one atom each of sodium, oxygen, and hydrogen; its formula is therefore NaOH; its proper scientific name is sodium hydroxide. It is also known as soda lye or simply as lye. It is very alkaline and corrosive.

² Cf. *Rules Governing Transactions between Members of the Texas Cottonseed Crushers' Association* (Dallas, Texas, 1927), pp. 71-76.

commonest tests applied to fats is the test of bleachability. This is done by mixing a given weight of alkali-refined fat with a given weight of fuller's earth¹ and then estimating the amount of color remaining in the fat or oil after this treatment.

Many fats and oils contain substances that are not triglycerids. These may be natural constituents or they may be adulterants or contaminants. The presence of a considerable proportion of them of course reduces the commercial value of the fat. The commonest of these is moisture. It is estimated very simply by placing a weighed portion of the fat in an oven heated to a temperature slightly higher than that of boiling water. The moisture is thereby driven off. The fat is then again weighed; the loss is regarded as moisture.

The determination of non-fat materials other than water is done by saponifying the fat by heating with strong caustic soda or potash² solution until all the triglycerids have been decomposed into glycerin and soap. These are soluble in water and may be washed away. What remains behind is the non-triglycerid part of the fat and may be weighed. It is known as the unsaponifiable matter. In practice the procedure is not as simple as this, but the basic principle is correctly stated above.

The determination of unsaponifiable matter must not be confused with the saponification number of a fat. The saponification number is the number of milligrams of potassium hydroxid required to convert one gram of the fat completely into glycerin and potassium soap. It gives information concerning the character of the fatty acids of the fat and in particular concerning the solubility of their soaps in water. The higher the saponification num-

¹ Fuller's earth is a special kind of clay that has the property of absorbing coloring matters. It derives its name from the fact that it has been used in the fulling of cloth to remove grease.

² Caustic potash is the compound of potassium analogous to caustic soda (see footnote, p. 16).

ber of a fat free from moisture and unsaponifiable matter, the more soluble the soap that can be made from it. The information is of especial importance to soap makers. Table 2 gives the saponification numbers of the commoner commercial fats and oils.

TABLE 2.—SAPONIFICATION NUMBERS OF COMMON FATS*

Fat or Oil	Saponification number
Rapeseed oil	170-179
Menhaden oil	190.6
Corn oil	188-193
Olive oil	185-196
Soy bean oil	193
Cacao butter	193.55
Linseed oil	192-195
Cottonseed oil	193-195
Lard	195.4
Mutton tallow	192-195.5
Peanut oil (arachis)	190-196
Horse oil	195-197
Beef tallow	193.2-200
Palm oil	196-205
Butter	220-233
Palm kernel oil	242-250
Coconut oil	246-260

* Data from J. Lewkowitsch, *Chemical Technology and Analysis of Oils, Fats, and Waxes*, pp. 395-400.

Examination of this table shows that butter ranks with palm kernel oil and coconut oil as having a very high saponification number. This is due to the fact that its triglycerids contain appreciable quantities of myristic acid and small quantities of lauric acid, both of which when they form soap combine with relatively more sodium than the more common acids of fats. These acids occur in undecomposed butter in chemical combination as triglycerids. Their sodium soaps are quite soluble in water. The high saponification number of coconut oil and palm kernel oil is due to the large proportion of lauric

acid and myristic acid that they contain. These oils therefore yield quite soluble soaps.

Before leaving the subject of the commercial chemical testing of fats, the "titre test" deserves mention because it is of much importance in certain branches of industry. The "titre" of a fat or oil is the temperature at which the mixture of fatty acids derived from it solidifies after it has been melted. The test is performed in several steps. First, the fat is completely saponified, usually by heating with a solution of caustic soda. Then the mixture of soaps thus obtained is treated with a strong acid, usually sulfuric, which takes the sodium away from the soaps, thereby converting them into free fatty acids. After these have been washed and dried they are melted and the temperature at which the melted mass solidifies when cooled is noted. This temperature gives an index to the consistency of the original fat, a matter of great importance to manufacturers of candles and of products like margarin, in which consistency and texture are of the utmost importance.

Finally, the viscosity of a fat is a property of commercial significance, especially to manufacturers of lubricants. It is usually estimated by comparing the length of time it takes a given volume of oil (or melted fat) to flow through a tube of small bore, or through a small orifice, with the time it takes an identical volume of water. Castor oil has the highest viscosity of any fat that is fluid at ordinary temperatures. Olive oil has the highest viscosity of any of the common vegetable oils. The viscosities vary greatly with the temperature. When fats are cooled to the solidifying point they can no longer be said to be viscous. They have become plastic.

III

FATS AND OILS TECHNOLOGY

The economic aspects of the fat and oil trade are so interwoven with the uses of these raw materials that some elementary consideration of the technology of fats and oils is necessary for a proper understanding of the economic situation. This is given in the present section.

COMMERCIAL PRODUCTION OF ANIMAL FATS

Animal fats—except butter—are separated by a process termed rendering or trying-out. The simplest method is to throw the fat-containing tissues into a kettle, heat them over an open fire till the fat has been cooked out, and then strain off the fat from the non-fatty material which is known as cracklings or greaves. More commonly the kettle is not heated by a direct flame but by steam, to avoid charring. This is done in a number of ways. The simplest is with a steam coil which projects into the interior of the kettle and comes in contact with the material to be rendered. Another common method is to use a “jacketed” kettle. This has a double wall and the heating is done by passing steam through the space between the walls. Sometimes, however, fats are not rendered dry but are placed in the kettle with water and then heated in any of the ways mentioned above; or else steam is blown directly into the water, a procedure wasteful of fuel. At the end of the heating the fat is allowed to rise to the top and is skimmed off.

The commonest rendering method of all is with steam under pressure at a temperature of 120°–130° Centigrade.

The material to be rendered is placed in a large strong metal cylinder known as a digester, which is then closed tightly. Steam under pressure is passed into it for some time—often as long as twelve to fifteen hours. The steam is then shut off, the apparatus is allowed to cool, and the fat is skimmed off the surface of the water, some of which was placed in the digester with the material to be rendered and some of which condensed from the steam during the operation. This is an efficient method of rendering, though it does not yield by any means the best product. It is very economical in regard to consumption of fuel and at these high temperatures tissues, even bones, release their fat quite completely. In consequence, the yields by this method are greater than by the others.

In the last few years a new method of rendering, known as "dry rendering" has been introduced. It is said to be the most economical of all for certain types of fat. The material is first dried to a low moisture content in a suitable machine. A part of the fat is obtained by merely allowing the hot material to drain. The remainder is secured by expression in an expeller or a press (see pp. 28).

When the process of rendering is such as to leave cracklings (scrap) or greaves, these retain considerable fat, most of which is often recovered by some form of expression either with a hydraulic press or an expeller.

The best quality of animal fat is obtained by rendering perfectly fresh material with water at low temperatures. It is in this manner that neutral lard and oleo stock (beef fat) are prepared for the manufacture of oleomargarin.

The nomenclature of the commoner commercial animal fats used in commerce is rather complex and there are many grades. Neither the nomenclature nor the grading is the same in all countries or even in all sections of the same country. In a general way, these, together with some of the processes by which they are produced, are described in the following paragraphs.

HOG FATS OR LARD

In America the fats from the hog are termed lard (French, *saindoux*; German, *Schmalz*) if they are edible, and grease if they are inedible. The grades of lard depend upon the part of the animal from which the lard is derived and upon the method of rendering.

The best grade of lard is known as neutral lard No. 1. It is obtained from the leaf fat of the hog, mainly kidney fat, and fat in the omentum. The omentum is a thin sheet of tissue attached to the intestines; in well-nourished animals it contains a good deal of fat. Before the development of the margarin industry, that is, before 1875, in great part it was rendered separately and marketed as leaf lard, commanding a higher price than other lard because of its great firmness and better flavor. It is still so marketed to some extent by smaller butchers and the small packing houses. In the larger establishments the omental and kidney fat are removed from the carcass at the earliest feasible moment, cooled and promptly rendered with pure water at a low temperature, usually not higher than 50° Centigrade. The product is known as neutral lard No. 1 and is used almost exclusively in the manufacture of oleomargarin.

This process does not recover all of the lard in the parts rendered. The remainder is recovered by cooking in digesters at higher temperatures and pressures. It is sold as leaf lard. It should be noted that it is a somewhat different product from the leaf lard of former times and from the leaf lard produced by small concerns that do not make neutral lard, for it contains only a portion of the leaf and kidney fat instead of all of it.

Neutral lard No. 2 is made from the back fat by exactly the same method by which neutral lard No. 1 is produced. The residue, treated in digesters, yields choice kettle-rendered lard.

A third grade of lard is made from trimmings and

other fatty parts by digesting at relatively high temperatures and pressures. It is known as prime steam lard. The solid residue in the digesters still contains some lard which is recovered either by expressing in presses or by cooking with a little acid. This product is classed as a grease.

The manner of cooling melted lard greatly affects its appearance. If allowed to cool without special precautions, it is apt to be translucent and to have the appearance which the American consumer attributes to a grease rather than the white, opaque, somewhat granular appearance which he expects in lard. It is therefore customary in packing houses to chill it rapidly. This is usually done with so-called lard rolls. These are large, smooth, hollow, metal cylinders which are revolved on a horizontal shaft. They are cooled from the inside with a current of brine, and the lard is run onto one side of their surface in a thin layer, thereby being chilled quickly. It is then scraped off automatically by a stationary scraper on the other side. The chilled lard drops into a trough in which is a worm conveyor or "picker" which churns up the lard, thereby giving it the desired color and texture, and conveying it still in the plastic state into storage tanks from which it flows into the containers for shipment. Sometimes the beating up of the plastic lard is so done as to incorporate air which makes it appear whiter and increases its volume though not its weight.

GREASES

Grease, which in packing-house parlance is merely inedible lard, is rendered with steam under pressure from packing-house offal, and from carcasses that have been condemned by the governmental meat inspectors as being unfit for food for one reason or another. It is graded according to color as white, yellow, or brown grease. White and yellow packing-house greases commonly contain only hog fat. Brown grease may also contain some beef and

mutton fat, for it includes the fat from the catch basins. In large packing houses great quantities of water are used which ultimately find their way into the sewers, carrying along in their passage not inappreciable quantities of fats. To recover these it is customary to let the waters settle in basins before they finally flow into the sewer. In these basins fat rises to the surface; it is then skimmed off and combined with the brown grease. As the waters come from all parts of the packing house in which cattle and sheep may be slaughtered as well as hogs, the brown grease naturally may contain beef and mutton fat.

Grease is also recovered from certain of the viscera, other offal, and especially the intestines. In former times, before the practice was restricted by the government, this was known as gut lard and mixed with other lard for edible purposes. It has a characteristic flavor which experts are able to recognize even in admixture. In slaughterhouses under federal inspection all offal of this kind must be worked up for grease.

Greases are sold on the basis of their color and of their chemical composition. The percentage of free fatty acid, of unsaponifiable matter, and of moisture are taken into consideration, and also the titre test. Greases are used chiefly in the manufacture of soap, candles, and lubricants. Before the enactment of the meat-inspection act in 1906 undoubtedly much that is now sold as grease was used for edible purposes. Today the meat-inspection act requires that such greases be denatured by the addition of petroleum products or other denaturant. Denatured white greases, when exported to Europe, have at times been treated there so as to remove the denaturant and they have then been used for food purposes.

CATTLE AND SHEEP FATS OR TALLOW

The fat from cattle and sheep is known as tallow (French, *suif*; German, *Talg*). Sheep fat is rarely used

for edible purposes because of the difficulty of removing its strong flavor and odor. It is widely used for soap and candle making and in lubricants. Beef fat is used for all these purposes and for food as well. The fat from the heart, caul, and around the kidney, which corresponds to leaf lard, gives the finest edible tallow. Its best grades are used to produce oleo stock (also known in Europe as *premier jus*) for the oleomargarin industry by the same process which is used to produce neutral lard. Beef tallow of good quality is also used in so-called lard compounds to give a stiffer consistency. Tallow, except for oleo stock, is usually steam rendered. Inedible tallow is graded and sold on the basis of color—sometimes also on the basis of its content of moisture, impurities, unsaponifiable matter (abbreviated to M.I.U. by the trade), and free fatty acid. If sold for candle making, the titre test is especially important, since it indicates the yield of solid fatty acid suitable for candle making that may be expected. This in practice is more variable than might be supposed, since in packing houses doing a local business more or less hog fat, which has a low solid fatty-acid content, may be mixed with inedible tallow.

PRODUCTION OF GARBAGE GREASE AND SIMILAR PRODUCTS

While in the larger packing houses under governmental inspection the term grease is generally limited to inedible hog fat, this is not always the case in all sections of the trade; one finds the term grease used for any inedible fat of semi-soft consistency. The trade, therefore, often distinguishes between "packing-house grease" and all other greases. In small establishments doing a local business, the term grease may be applied to a product of variable origin and containing more or less tallow and fat recovered from retail butchers' scrap and the like.

Garbage grease is one of the more important of the waste fats. In some cities household, restaurant, and hotel

offal is separated into garbage proper, consisting mainly of food offal, and into rubbish and trash of all kinds. Grease from the garbage is recovered usually by one form or another of steam rendering (see p. 20). It is sold mostly to candle makers. The disposal of garbage presents a serious problem to municipal administrators, and methods of rendering other than by steam, including solvent extraction, have been proposed. Opinions differ concerning the value of different methods. The recovery of garbage grease is sometimes profitable, sometimes not, depending upon local conditions and the general level of prices of fats prevailing at the time the grease is sold.¹

In some cities dead animals of various kinds are rendered with the garbage. In others this is done by privately owned rendering companies which work up such material, and at times also the garbage from hotels and restaurants and the scraps from retail butchers' shops. The material produced by them is sometimes known as horse oil which may, however, and usually does, contain fat from other sources than the carcasses of horses.

PRODUCTION OF VEGETABLE FATS

Vegetable fats, except in special cases, are not produced by rendering. The principal exception is the palm oil produced by African natives in the home of the palm. They boil the crushed and more or less decomposed fruits with water and then skim off the oil.

The commoner method of producing vegetable fats is by expression. This process involves several steps. The first is the preparation of the seeds, which consists of the removal of the shell or hull. This decortication is not always necessary, as in the case of fruits like the olive or small seeds like rape or flax. Sometimes it suffices merely

¹ The several methods of garbage disposal are feeding to hogs, dumping (usually at sea), incineration, and recovery of grease, or combinations of them. The question of the disposal of garbage is so tied up with local politics that it is impossible to determine where the path of efficiency lies.

to crack or crush the shell without removing it. Decortication is usually done by special machines; in the case of the coconut, however, it is done by hand. The coconut presents a special case in another respect. The meat which has been separated from the shell and husks by hand is commonly dried either in the sun, or over fires, or by special machines before it is treated further for the production of oil. The dried product is known as copra.

The second step, which follows decortication when this is necessary, is crushing or grinding. This is done either between steel rolls or between mill stones or both. Hence the factories are known as oil mills and the process as oil crushing or oil milling.

The material is now ready for the expression of the oil in presses of various types. This is sometimes done without heating the material, as in the case of olive oil. Such oils are known as cold-pressed oils. Sometimes the residue from the pressing is reground with or without the addition of water, again pressed, and a second portion of oil obtained. The first pressings of olives is known as virgin oil. If the olives from which it is made are of good quality, this oil represents the highest quality.

Since cold pressing does not extract all the oil, it is practiced only in the production of a few special edible oils, the natural flavor of which is highly prized. They are used without further refining other than clarifying and filtering. The oil unextracted by cold pressing is recovered in large measure by grinding up the residue from which the cold-pressed oil has been extracted, cooking it (usually with steam), returning it to the presses, and again expressing the oil. This is known as hot-pressed oil.

The great bulk of vegetable oils—coconut, palm kernel, cottonseed, peanut, etc.—are extracted only by hot pressing. All these oils require refining before they are suitable for edible uses.

The expression of the oil is practiced either with

presses or with special machines known as expellers. For descriptions of the construction of these machines, the reader is referred to special treatises.¹ Here it suffices to say that the presses are usually hydraulically operated and are commonly capable of exerting very great pressures. They operate discontinuously—that is to say, they act only upon one charge at a time. After the oil has been expressed from this the press must be unloaded and refilled with a fresh charge of the ground oil-bearing material. Hence the labor costs of operation may be considerable. The expeller, on the other hand, operates continuously and the labor costs are correspondingly low, though maintenance and power charges are said to be high. The expeller is built on the same principle as the ordinary meat chopper or sausage machine which nowadays is to be found in most kitchens. The oil-bearing material is fed into one end of a cylinder within which a power-driven worm conveyor forces the material to the other end of the cylinder and out against resistance, exactly as though it were sausage meat. The pressure exerted in the process squeezes out the oil. In some factories the material, if very rich in oil, is first passed through an expeller to remove a part of the oil, then reground and recooked, and finally expressed in a hydraulic press.

The hydraulic press when skilfully operated removes the oil somewhat more completely than the expeller. However, neither does so completely. From 4 to 8 or even 10 per cent of oil may remain in the residue which is known as oil cake, sometimes also as press cake or pressed cake. A method has been devised to recover this oil. It is known as the solvent-extraction process. It consists of grinding the cake to a meal and then extracting or leaching it with a volatile liquid in which the oil is freely soluble. The extract is then drawn off from the cake into a still where

¹ T. W. Chalmers, *The Production and Treatment of Vegetable Oils* (London, Constable, 1920); Lewkowitsch, *op. cit.*

the solvent is distilled off and recovered, leaving the oil behind in the still. The solvent most commonly used is benzene, although carbon bisulfid, petroleum products, and other liquids are also used.¹ The oil obtained is inferior in many cases to that obtained by expression. It is especially so when the solvent used is carbon bisulfid; such oils are known as sulfur oils.

In Europe the solvent extraction of oil cake for the recovery of residual oil has been practiced quite extensively. In the United States it has been employed principally at times of high prices or for special purposes. The chief difficulty at present is that the ideal solvent remains to be found. Those commonly in use or proposed either introduce a serious fire hazard, or else in time they corrode the equipment, or finally they leave a bad odor or taste in the cake, which impairs its value as cattle feed. It has been proposed to do away with presses and expellers altogether and to dissolve out the oil from original oil-bearing raw material by solvent extraction, and there are some plants of this kind in operation in Europe. In America, however, so far as it has been possible to learn, no such plants are now in operation.

REFINING

Refining has for its object the removal of free fatty acids and other objectionable substances—principally nitrogenous and mucilaginous matters. The principle involved has already been outlined (p. 16). The melted fat or oil is treated with a little more than the requisite amount of strong aqueous caustic soda solution to convert the free fatty acid present into soap. The oil and the alkali solution are thoroughly stirred together and sometimes warmed. The mixture is then allowed to separate. The result is that the oil freed from fatty acid floats on

¹ For details the reader is referred to the treatises by Chalmers and Lewkowitzsch above cited.

top of a layer of soap, alkali solution, and other impurities, which is drawn off. The oil is then washed with water to remove the soap, alkali, and other impurities, when it is ready for the decolorizing or deodorizing process. There are other methods of refining, but this is the one most commonly used in America.

The under layer of soap and other impurities, which is drawn off from the oil, consists of solid matter mixed with some water. It is known as fooms, probably because it collects at the foot of the tank. A large proportion of it is soap. It may be sold to soap makers for use in the lower grades of soap, the price being based on the percentage of fatty acid present in it. Hence it is also known as soap stock. Or it may be treated with strong sulfuric acid to set free the fatty acids contained in it. These then float to the surface, are skimmed off, and sold to the soap or candle maker. This product is known commercially as acidulated fooms. It pays to produce it rather than to sell ordinary fooms whenever the freight from the refinery to the soap maker is considerable, for by converting fooms into acidulated fooms the weight is reduced about one-half. A third use for fooms is to convert it into washing powder by mixing with a suitable amount of soda ash.¹ The soda ash takes up the water in the fooms and crystallizes with water of crystallization, thereby converting the fooms into a hard, dry cake which needs only to be broken up and ground to be salable as washing powder. At the same time the soda ash bleaches the fooms and improves the color.

While with the exception of virgin oils (see p. 27) the great bulk of vegetable oils destined for food use is refined, this is not the case with animal fats. It was formerly the custom to refine the poorer grades of lard and of

¹ Soda ash is soda heated till its water of crystallization has been driven off. Soda is sodium carbonate, Na_2CO_3 ; in the crystalline form in which it is found in commerce it contains water of crystallization, and has the formula $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$. Soda ash in contact with moisture tends to take up water and crystallize.

tallow to make them more suitable for edible purposes. The practice was to wash them in the molten state with a weak alkali solution, or to treat them with alum or other chemicals or with fuller's earth. Such refining is no longer permitted in federally inspected packing houses. About the only practice now allowed is to let the fat "settle" with the addition of some salt in order to remove traces of water and any fragments of tissue and fibre that may be present, or to treat with fuller's earth or other inert decolorizing agent. It is reported that in many regions of Europe refining of animal fats for food use is not prohibited.

DECOLORIZING OR BLEACHING

Most crude vegetable oils are deeply colored. They must be bleached. There are many methods, but the one in most general use in America is to agitate them, after they have been refined, with some solid material which absorbs the color. The usual material is fuller's earth (see p. 17). Since the war various forms of carbon and charcoals have also come into use, usually in combination with fuller's earth. This is the result of the stimulus to the production during the war of good absorbent carbons for use in gas-masks. To the dry oil dry fuller's earth is added, usually only a few per cent, the quantity depending upon the character of the oil and the temperature; the mixture is then warmed, usually to less than 80 degrees Centigrade, and agitated for one-half to one hour. It is then pumped through a filter press¹ which retains the

¹ A filter press is an assemblage of square screens of canvas all of the same size. They are placed on a horizontal rack like books on a shelf. Thus a series of thin, flat compartments is formed very much as though one were to stack upright along a shelf a series of ordinary square window-screens in which the wire netting had been replaced by canvas. The canvas is usually backed by a corrugated metal plate so that it will not burst under pressure. In the filter press the frames are pressed so tightly together by means of a powerful screw that liquid cannot escape between them. The frames of the screens are perforated with a set of holes so placed as to form a continuous tube reaching from one end of the stack to the other when the screens are assembled. This

fuller's earth and permits the oil to run out clear. An appreciable amount of the oil remains in the earth retained in the press at the end of the operation. A considerable proportion of this is sometimes recovered by forcing dry steam through the press which carries out with it much of this residual oil. Nevertheless appreciable amounts of oil remain behind. It has been proposed to recover these by the solvent extraction process but this does not seem to be done at the present time in America.

Since the necessity of using fuller's earth involves not merely expense but also loss of oil and since, therefore, the costs of decolorizing rise with the amount of earth it is necessary to use, the price paid for an oil, and especially for cottonseed oil in the United States, depends among other factors upon the ease with which it may be decolorized or bleached. Furthermore, if too much fuller's earth has to be used, the oil acquires an earthy flavor. The American trade has, therefore, established two classes of cottonseed oil—viz., bleachable and unbleachable. A bleachable oil is one that may be reduced to a very definite color standard when treated in a specifically prescribed way.¹ All other oil is unbleachable or "off" oil.

DEODORIZING

Many oils even after they have been refined and decolorized to transparent whiteness retain a disagreeable odor and flavor. This is especially true of cottonseed oil. Such oils may be deodorized by blowing steam through them, since the substances responsible for odors and flavors are usually volatile. A still more effective way is

tube opens into every other compartment. Through this tube the liquid is pumped into these compartments and forced through their canvas walls into the adjacent compartments which do not communicate with the tube. The canvas holds back the fuller's earth and only permits clear oil to ooze through into the adjacent compartments. The latter are provided with channels which permit the clear oil to escape to the outside where it runs into storage tanks.

¹ *Rules Regulating Transactions in Cottonseed Products among Members of the New York Produce Exchange*, Rule 22, Sec. 4, p. 20.

to blow the steam through the oil after it has been heated to a high temperature, say 340° Fahrenheit. The most effective method is to carry on this treatment in a vacuum. This is the method now widely used to prepare cottonseed oil for use as a salad oil.

WINTERIZING

As stated in an earlier section (p. 11), fats and oils are mechanical mixtures of a number of triglycerids. Now, different triglycerids solidify and melt at different temperatures. Therefore if an oil consists of a number of triglycerids, some of which remain liquid at low temperatures while others become solid, and such an oil is exposed to a low temperature, more or less sediment forms consisting of the triglycerids that separate out at that temperature. Indeed, the oil may be completely converted into a solid cake if it is cooled down far enough. Every housewife who has permitted a bottle of olive oil to stand outdoors in winter has made this observation. This solidification was especially objectionable when fatty oils were used in lamps. It is objectionable in salad oils today because the housewife, being ignorant of the nature of the phenomenon, is apt to believe the oil spoiled. Manufacturers, therefore, subject such oils to a process which prevents the separation of solids in all but the most extremely cold weather. An oil so treated is known, naturally, as a "winter" oil, and the process is known as "winterizing." Conversely, an oil that has not been "winterized" may be known as a "summer" oil. Winterizing is a very simple procedure. The oil is very slowly chilled in large tanks to the temperature at which it is to remain clear. It is allowed to stand quietly at that temperature for a considerable length of time to permit the separation of the solid crystalline materials from the liquid to become complete. The oil with the suspended solid matter is then pumped through filter presses which retain the solid and

allow the liquid to run out. The solid remaining in the press is known as stearin because largely composed of the glycerids of stearic acid. It is used to stiffen lard compounds, and in soap and candle making.

PRODUCTION OF STEARIN

The amount of stearin obtained by winterizing oils is small and would not supply the demand for it. Therefore, not merely oils but also solid fats are treated to separate them into a more solid and a more liquid fraction. The fat is melted and allowed to cool slowly in large tanks to a given temperature which is so chosen that the solid portion which gradually separates has the desired melting point. The fat is held at this temperature for some time in order to permit the solid portion to form completely. Cooling slowly and prolonged holding have another effect. The solid portion is caused to separate in coarse granular masses rather than in fine particles which could not so easily be freed from the liquid portion. Hence this process is known as "graining."

When it is judged that the mixture has the desired granular texture, it is placed in a powerful press and the liquid portion squeezed out and thus separated from the solid portion, the stearin. In this manner are prepared lard stearin and lard oil (usually from grease, less nowadays from lard), and oleostearin and oleo oil from edible tallow. Some tallow stearin and tallow oil is also produced from inedible tallow. Lard stearin, if produced from lard, is used especially to mix with other lard that is destined for a warm climate to stiffen it. Such lard is known in America as "Cuba lard." Lard stearin from grease is used for soaps, candles, and lubricants. Lard oil was formerly widely used as an illuminant instead of sperm oil. Though it is still so used to a very limited extent, it has been displaced nearly entirely by petroleum products. Lard oil is used in compounding lubricants and

especially as a so-called cutting oil, i.e., an oil used to lubricate the cutting edges of steel tools in metal working. Oleostearin is used principally in lard compounds, in shortening agents, while oleo oil is used in oleomargarin and for shortening. Tallow stearin is used in lubrication, candle and soap making, while tallow oil is used principally in lubrication and soap making.

HYDROGENATION

It has already been stated (p. 13) that many of the fats are not saturated with respect to hydrogen and that they may be made to combine with this gas by chemical treatment, a process known as hydrogenation. As it happens, practically all the important unsaturated triglycerids, e.g., triolein, trilinolin, and trilinolenin, are liquids at ordinary temperatures; hence fats which contain them in considerable proportions are oils or, if the proportion is smaller, they are soft solids. On the other hand, the important saturated triglycerids, e.g., tristearin and tripalmitin, are solid, and fats which contain them in preponderating proportion are firm at ordinary temperatures. Now, since hydrogenation converts unsaturated triglycerids into saturated ones, it changes oils into solid fats. This process is of the greatest commercial and economic importance, since it permits of the conversion of oils into fats and thereby widely extends the substitutibility of oils for solid fats and even of oils for one another. In practice, hydrogenation is widespread, but it is used far more for edible than for industrial products, since the cost is of the order of magnitude of one-fourth to one-half a cent a pound, which may be prohibitive for many industrial uses. Moreover, in the inedible field the possibilities of substitution of one natural fat or oil for another are greater than among edible products. Nevertheless, the introduction of hydrogenation has had a profound effect upon the fat and oil industries and trade of the world, for

not merely has this discovery widened the uses of oils but the hydrogenated product is usually improved in keeping quality and in color, odor, and flavor as well.

The commercial process of hydrogenation is based upon the purely scientific researches of the French chemist Sabatier and of his students. Though they discovered the scientific principles, commercial application of them was made by others who have taken out a host of patents. The principle itself is simple. To the perfectly dry oil is added a small amount of very finely divided nickel or compound of nickel, called a catalyst.¹ Other metals may be used, but nickel is the one most widely employed. The oil with the nickel suspended in it is placed in a tight, strong metal vessel and heated. At the same time pure hydrogen gas is forced into it until a definite pressure is reached. The vessel contains, commonly, some mechanical device to churn up the oil as the gas passes in so that all parts of the oil may be mixed intimately with the hydrogen. The process is interrupted when a sample of oil withdrawn from the vessel is found to have the desired properties. The oil is then withdrawn and cooled sufficiently to permit of its being filtered to remove the suspended nickel.

SUBSTITUTABILITY AS A TECHNOLOGICAL OBJECTIVE

Hydrogenation, refining, deodorizing, decolorizing, stearin pressing, winterizing, and a large number of other technological processes which have been evolved in the course of the last 150 years have all had one object: to make one fat substitutable for another. These substitu-

¹ A catalyst or catalyzer or catalytic agent—the terms are synonymous—is a substance which affects the velocity of a chemical reaction without itself appearing in the final product. In the present case nickel is the catalyst. It speeds up the rate at which the oil absorbs hydrogen and may be recovered in undiminished amount at the end of the reaction. A catalyzer cannot start a reaction; it merely modifies the velocity of the reaction. A large quantity of the reacting substances can be transformed by a very small quantity of the catalyzing agent.

tions have at different periods had different purposes. When candles were important and hard fats were in demand, the preparation of a hard fat from a soft one by separating the stearin was discovered. When with the development of lamps burning oils became more important, the same method of pressing stearin made fluid oils derived from harder fats available. When with the development of the production of vegetable oils these became more abundant than solid fats, lard compounds were developed, facilitating the use of oils as cooking fats in countries where hard cooking fats are preferred to oils. This was followed by the introduction of hydrogenation which widened the substitutibility of oils for hard fats. It still remains for chemists to discover a commercial method of converting a saturated fat into an unsaturated drying oil; but even without it the most striking characteristics of the evolution of fat and oil technology have been to increase greatly the possibilities of substitution of one fat for another. If substitution is not more widely practiced, the deterring factors are price, cost of the treatment, and finally the fact that despite the great progress in the treatment of fat it is as yet not possible to modify all fats so as to give each and every one of them the peculiar properties of every other. Some of these peculiarities will be treated in some detail in a later section on the utilization of fats and oils.

Having sketched in outline the principal technological processes, we may now consider the major types of uses of the fats and oils and the way in which the various products are manufactured.

SOAP MAKING

The principles of soap boiling have already been indicated (p. 9). They consist in splitting (hydrolyzing, saponifying) the fat or mixture of fat into glycerin and fatty acids and the conversion of the fatty acids into the

salt usually of sodium (hard soap) or of potassium (soft soap). There are many methods, but they all may be divided into two groups. Soap is formed either in one operation or in two. If it is done in one operation, the fat is simply treated, usually hot but sometimes cold, with the appropriate amount of a solution of caustic soda or potash. This forms soap and glycerin. There are a number of methods of separating the soap from the water, glycerin, the excess of alkali, and impurities, but the commonest is simply to add a considerable amount of ordinary salt. This dissolves in the water present and forms brine. Now, soap is but slightly soluble in strong brine. Therefore, the mixture separates into three layers: an upper layer consisting of the purer portion of the soap; a middle layer, dark in color, consisting of impure soap and known as *nigre* (from the French *nègre*, black); and a bottom layer of brine containing glycerin. The upper layer is run into molds or otherwise formed into the well-known commercial soap units. The *nigre* is worked over and purified in various ways and finally worked into soap. The brine may be run into the sewer ultimately or the glycerin may first be recovered from it.

If soap making is carried on in two steps, the first is to split the fat into glycerin and free fatty acid. This may be done in many ways, but the end result is that a mass of fairly pure fatty acids is obtained. The second step is to treat them with the proper amount of caustic soda or sodium carbonate to convert them into the corresponding soap, which is then worked in the customary way.

CANDLE MAKING

Up to the early part of the nineteenth century candles were made from beeswax, spermaceti, or tallow. Those made from the first two were the firmest and gave the best light; but they were also expensive and became more and more so with the decline of whaling, for spermaceti is

a solid wax which separates from the oil obtained from cavities in the head of the sperm whale.

To meet the scarcity of beeswax and spermaceti, candles began to be made from stearin. By the 1830's, however, they began to be made from the solid fatty acids obtained in the saponification of fat, and this process has remained important to the present day. It consists in splitting tallow, grease, stearin, or any mixture of them into glycerin and free fatty acids by any suitable method. Thus a mixture of free fatty acids is obtained which, like the fats from which they were produced, consists of both more fluid and more solid acids. The solid portion is separated from the fluid portion by cooling, graining, and pressing (see p. 34), much as lard stearin is separated from lard. This solid portion is known in the trade as "stearic acid" and the candles made from it as "stearic" or "stearin" candles, although it is by no means pure stearic acid. It is nearly always a mixture of palmitic and stearic acid, as well as of any other solid acids that happen to be contained in the raw materials from which it was produced. The oil which is obtained in expressing the "stearic acid" is known as "red oil." It consists mainly of impure oleic acid and is used either in soap making or as soap for use in woollen and other textile mills. From the "stearic acid" candles are made by melting and casting in suitable molds. To overcome their brittleness they are usually mixed with some other material such as paraffin. Indeed, paraffin has to some extent displaced "stearic acid" in candles.

The candle maker in purchasing his raw materials is primarily interested in the amount of solid acids they contain, for it is these that he wishes to use in his candles. For this reason he prefers fats with a high content of solid fatty acids. As the titre test (p. 19) is an index of this, it is of especial value to him. Since the content of solid fatty acids is usually comparatively high in tallows and

stearins, he prefers these fats to greases and oils. In buying raw materials he is also interested in their color, for from dark greases are obtained dark acids from which white candles cannot be made directly. The acids must either be bleached or distilled. The latter is the preferred practice. The common fatty acids are not readily volatile at the pressure of the atmosphere. When distilled under ordinary conditions they char and a great proportion is converted into a sort of pitch. If, however, the distillation be done in a high vacuum, there is but little decomposition and but little pitch is formed. The acids that distill over are pure and white even though the grease from which they are produced may have been very dark. The candle maker is thus enabled to utilize raw materials that would otherwise be of no use to him. The soap maker also uses the process to utilize similar materials. It enables him to make white soaps even from dark materials.

LUBRICANTS

Until the rise of the petroleum industry the most important lubricants were tallow, greases, and vegetable oils. For about seventy-five years now petroleum products have gradually been displacing them, but this displacement has by no means been complete. Material quantities of fats and oils are still used in lubrication, usually mixed with greater or lesser proportions of petroleum derivatives. It is therefore worth while to consider the manner in which fats and oils are used in lubrication. Only non-drying oils are suitable, for drying and semi-drying oils absorb oxygen and become sticky and gummy.

Fats are still used in so-called cylinder oils, used to lubricate the pistons within the cylinders of steam engines. They are no longer used alone but mixed in relatively large and increasing proportions with mineral oils. Tallow, greases, and lard oil are used in all types of engines except marine engines, in which compounds contain-

ing rapeseed oil are the only ones acceptable. However, not only is the percentage used on the decline but the total amount of cylinder oils consumed is diminishing relatively because of the displacement of the steam engine by the steam turbine, the internal combustion engine, and the electric motor.

A very large use of lubricants is in automobile engines. Motor oils are for the most part purely mineral products. In a few brands, however, some lard oil is mixed with mineral oils.

Lubricating greases, also extensively used for automobiles as well as for other machinery, consist of mixtures of mineral oil, animal grease or tallow, vegetable oil, and soap made from such grease, tallow, or oil. The soap apparently serves not merely as lubricant but also to emulsify the mixture so as to give it the desired consistency. Such greases represent one of the more important lubrication uses of fats.

Another considerable use of fats and oils for lubrication is in metal working, to lubricate the cutting edge of tools. Lard oil is perhaps the preferred oil for this purpose. In recent years, with the development of high-speed tools, so-called soluble oils are being used. These consist of mixtures of animal or vegetable oil, mineral oil, and alcohol with some other minor ingredients. Soluble oils are not used directly but are first mixed with ten to twenty times their volume of water. They at once disperse in the water to form a milky emulsion—hence the term soluble oils. Their increasing use tends to cut down the amount of fat of various kinds used in cutting oils.

MARGARIN

Margarin is designed to furnish a substitute for butter. It was invented in 1869 and was originally a purely animal product. It is usually made today either from a mixture of animal and vegetable fat or from vegetable products

alone. The most important materials are neutral lard, oleo stock (*premier jus*), oleo oil, coconut oil, palm kernel oil, peanut oil, cottonseed oil, oleostearin, lard stearin, and sesame oil. Any two or more of these are mixed together so that the mix has a melting point from 26° to 27.5° Centigrade. The different formulas used vary greatly and sometimes depend upon the price relations of the different fats. The mixture chosen is melted. It is then cooled and mixed with skim milk "ripened" or soured with a pure culture of bacteria. The mixture is agitated to emulsify the fat and then cooled by causing it to fall against a spray of ice-cold water which carries it into a tank of ice water from the surface of which it is skimmed off. It is thereafter handled exactly like butter. In Europe, in some factories, it is cooled on a cooling drum instead of with ice water, but apparently this machine is not used in the United States.

Margarins, then, are mixtures of fat emulsified in skim milk and made into the semblance of butter. In the United States there are two main types: one consists usually of neutral lard or oleo oil and cottonseed oil; the other of coconut oil and peanut or cottonseed oil. Hydrogenated fats may also be used, usually so-called hydrogenated coconut oil, which is usually a hydrogenated mixture of coconut oil with a small proportion of peanut or cottonseed oil.

LARD COMPOUNDS

The production of lard compounds began in the late 1870's as adulteration of lard with tallow or beef stearin. Soon thereafter, cottonseed oil was also used as an adulterant. The proportions of tallow or stearin and of cottonseed oil were gradually increased until they formed the major constituents and lard the minor ingredient. By 1890 brands were on the market which contained only enough lard to give the characteristic flavor. Up to that

time these products were sold as refined lard, pure family lard, etc. About this time, owing to a Congressional investigation, manufacturers began to brand products of this kind as lard compounds, the designation by which they have been known ever since.

About 1908, shortly after hydrogenation began to be practiced in the United States, a new type of cooking fat began to be introduced which consisted of cottonseed oil hydrogenated to the desired consistency. Products of this kind have not usually been marketed as lard compounds but under their own distinctive brand names.

Today there are three principal types of lard compound on the market:

1. The original type of lard compound consisting of beef tallow or beef stearin and a vegetable oil, preponderatingly cottonseed oil. It may also contain some lard or lard stearin.
2. A mixture of cottonseed oil more or less completely hardened by hydrogenation and a vegetable oil, preponderatingly cottonseed oil.
3. Cottonseed oil partially hydrogenated to the desired consistency.

The method of manufacture is relatively simple: The component fats, so proportioned that the mixture has the desired melting point, are melted together. The resulting liquid is run onto hollow revolving cylinders chilled from within, known as lard rolls (see p. 23). The mixture is thus rapidly chilled, thereby acquiring the texture and appearance of lard. The chilled fat is automatically scraped off and drops into a trough in which a worm conveyor beats it up and transports it to storage tanks from which it is packed into the shipping containers. Sometimes the conveyor is so arranged as to beat air into the compound, thereby increasing its volume and lightening its color.

IV

CONDITIONS AND TRENDS OF PRODUCTION

INFLUENCE OF AGRICULTURAL EVOLUTION

Present-day economic relationships between vegetable and animal fats are best understood in the light of certain aspects of the development of world agriculture during the nineteenth century. Before that time sheep and cattle raising was the only form of agriculture possible in vast regions of grass lands because of scarcity in these lands of fuel, building materials, means of transportation, and water. In such regions carcass fats, together with hides, were the major marketable products of agriculture, for these are not very perishable. Meat, because superabundant and perishable, had little value. Cattle were slaughtered for their hides and tallow; sheep were sheared, or were killed for their pelts and tallow. It was not so long ago that this was the practice in the Southwest of the United States, in Argentina, and in Australia. It is still the marketing method in some remote regions, for example, in certain sections of South America. As late as the 1850's, probably even in the 1860's in Chicago, Cincinnati, and elsewhere in the Middle West, only the hams and shoulders of a large proportion of the hogs slaughtered were marketed as meat. The remainder of the carcass was steam rendered for lard. As late as the 1870's cattle were slaughtered for their hides and tallow in California. In other words, in certain stages of agriculture and in certain remote regions hides and carcass fat are the major products of animal husbandry; meat is either worthless or a mere by-product. The world over, the area of grass lands that was producing carcass fat as a major product was so

vast during perhaps the first three-fourths of the nineteenth century as to exercise a great influence on animal husbandry everywhere, as well as on the world trade in fats and oils. The hides and wool were the first products, the fat the second product, the meat the last product.

Gradually, however, the grass lands were brought more and more under the plow. Three sets of inventions made the growing of crops possible in these areas. One was the railroad, which not merely made the transportation of crops to market practicable but also served to bring to the farmer fuel and building materials in exchange. Later came the modern steamship, port storage facilities, and still later the present-day refrigeration. The second invention was well-drilling machinery, which supplied water for domestic use and for irrigation. The third was agricultural machinery, which made extensive agriculture possible.¹ In these grass lands the rainfall is generally too scanty for high crop yields or the soil may be of too poor a quality, or both. On such land a farmer must work a considerable acreage to produce enough to support a family. If he must work the land with a spade or a primitive plow and a bullock he cannot cultivate a sufficient area. To exist he must practice extensive agriculture upon a considerable acreage, but this requires machinery operated by an abundance of draft animals or by engines of one sort or another. It is only within the last half-century that large sections of southern European Russia, of the United States, of Australia, and of Canada have become grain producers. Before that time they were cattle ranges and sheep pastures. At the present time this conversion of the ranges into crop land is approaching completion.

ANIMAL FATS AS BY-PRODUCTS

There are now left few regions of the earth where hides and carcass fats remain major products of animal

¹ Cf. O. E. Baker, "The Potential Supply of Wheat," *Economic Geography*, March 1925, I, 15.

husbandry. In most regions, as a result of a gradual shift in relationships, meat has become the major product and fat a by-product in the sense that much the greater return is received from the meat and the lesser return from the fat and other products. The capacity for meat production has not yet reached its limits.

Why have fats become subordinate to meats in the carcasses of animals? To answer this question it is necessary to recognize first that it has two aspects. The more conspicuous involves the change that has occurred in the more remote regions and for this the explanation is obvious. Where once the meat was valueless because there was no market near enough to be reached, settlement of these remote regions has expanded the local market, and improved transportation facilities and refrigeration have opened up distant markets.

The other aspect of the question is more obscure, yet perhaps more important. Meat has probably always been the primary product of animal industry in regions close to centers of population. As improved transportation and refrigeration have brought to these centers of population the meat as well as the fats produced in remoter regions, it might be supposed that in the centers of population prices of meats should have fallen relative to prices of fats. But on the contrary it is the prices of fats that have declined. The reasons are many; the decline in prices of fats relative to prices of meats in the centers of population is the resultant of a number of factors, some involving supply, some demand. On the supply side, one factor has been the development of improved breeds of animals, particularly cattle, capable of laying on more fat. These heavier fat-producing breeds have been adopted chiefly because of the better quality of meat produced, but a consequence has been a larger production of fat per pound of meat.

The supply of animal fats is strongly influenced by the

demand for meat, since it is the price of meat which is chiefly influential in determining the profits of animal husbandry. The direction and the amount of these changes over the last 50 years are by no means clear. It appears that in the United States the demand for meat per capita probably declined between 1907 and the beginning of the war and has since increased slightly. Even for the United States and for these recent years, the data do not justify positive conclusions, and for other regions and for other years there is too little evidence to justify even a guess as to the direction in which the supply of animal fats has been influenced by the demand for meats.

On the demand side, there has been an important increase for fats in general, arising from the greatly increased consumption of soap. The most powerful influence on the supply side, however, has been the development of new sources of vegetable fats. In consequence, vegetable fats have been substituted for animal fats on a large scale and in many uses. The production of cottonseed, coconut, and palm kernel oil has been greatly expanded. As the demand for cotton has increased, production of cottonseed has of necessity increased likewise. New areas opened up in the tropics have provided abundant supplies of coconut and palm kernel oil at low prices. With the increase in supplies of vegetable oils came also the development of the process of hydrogenation, whereby the vegetable oils could be transformed into solid fats and brought into direct competition with the animal fats.

The relation of meat (in the stricter sense) to fat can be shown both by comparisons between animals of different ages and by comparisons of the prices of different parts of the carcass. Let one compare the bacon type of hog with the lard type of hog. The bacon type of hog is finished at an earlier age, commands a premium in the livestock market, and when the disposition of the entire carcass is computed, it is observed that the lard and salt

pork fractions are relatively low. In the case of the lard hog, the animal is finished later and reaches a larger weight; the heavier the animal, the lower the price per pound as a rule; and when the disposition of the carcass is computed, it will be found that the lard and salt pork fractions are relatively high. Let the commercial prices for loins, hams, shoulders, bacon, lard, ribs, and mess pork be compared, as in Table 3. The loin, bacon, and ham carry high prices and the lard and salt pork a low price.

TABLE 3.—PRICES OF HOGS AND HOG PRODUCTS IN CHICAGO,
1913-14 AND 1921-26*
(Cents per pound)

Year	Live hogs	Smoked hams	Bacon: short clear sides	Fresh pork loins	Pure lard	Short ribs	Mess pork
1913.....	8.35	16.6 (199)	12.7 (152)	14.9 (178)	10.8 (129)	11.37 (136)	10.81 (129)
1914.....	8.30	16.7 (201)	13.2 (159)	15.4 (186)	10.2 (123)	11.09 (134)	10.44 (126)
1921.....	8.51	26.8 (315)	13.5 (159)	22.5 (264)	13.2 (155)	9.52 (112)	10.75 (126)
1922.....	9.22	26.5 (287)	14.1 (153)	21.7 (235)	13.1 (142)	11.21 (122)	12.37 (134)
1923.....	7.55	21.2 (281)	12.0 (159)	18.0 (238)	13.9 (184)	9.81 (130)	11.95 (158)
1924.....	8.11	20.2 (249)	14.4 (178)	19.1 (236)	14.7 (181)	11.28 (139)	13.14 (162)
1925.....	11.81	27.1 (229)	22.3 (189)	25.0 (212)	17.9 (152)	16.97 (144)	18.79 (159)
1926.....	12.34	30.8 (250)	20.1 (163)	27.8 (225)	16.9 (137)	15.48 (125)	18.30 (148)

* *Agriculture Yearbook, 1926*, pp. 1105 and 1110; also G. C. Haas and Mordecai Ezekiel, *Factors Affecting the Price of Hogs* (U.S. Department of Agriculture Bulletin 1440); 1926 prices of short ribs from *Price Current-Grain Reporter*, November 9, 1927; 1926 price of mess pork computed from weekly data in *National Provtstoner*. Figures in parentheses indicate percentage of each price to the live-hog price for that year.

The disparity in prices is so pronounced as almost to justify calling the lard a by-product. The high price of the

lean cuts must carry the low price of the salt pork and lard; and since the load is heavier in the case of lard hogs than of bacon hogs, this represents an advantage for the latter, considered from this viewpoint alone.

This conclusion is confirmed by inspection of the practices current in the retail sale of fresh pork. The loins, chops, and steaks—the cuts that are prepared by broiling rather than by roasting—carry the highest prices. Next come the relatively lean cuts that may be either broiled or roasted, such as the rump. Then come the fatter cuts that can be neither broiled nor roasted, but must be boiled, stewed, or sautéd. As meats are sold at retail, the excessive fat is cut off and thrown away, to be rendered or sold to renderers for what it will fetch. In the household a further trimming off of fat occurs, representing largely a waste. Owing partly to preference for the quality of meat in the parts of the animal sold as steaks and roasts, but largely also to the co-existence of the fat, the lean cuts carry a higher price and the fat cuts carry a lower price.

In the case of beeves, it is a fair statement of retail practice to say that the hind quarters must carry the front quarters, and that in the case of each of these a relatively small fraction of the leaner, more highly esteemed cuts (steaks and roasts), carries the balance of the quarter. Lamb is preferred to mutton because it is leaner and younger. The premium for young, lean poultry over old, fat poultry expresses the same fact. Right through animal husbandry (outside of dairying), therefore, we find the fat to be at best a subordinate product, if not indeed a by-product; the lean is the principal product.

VEGETABLE OILS MAJOR PRODUCTS

If now the vegetable fats and oils be compared with carcass fats in regard to manner of production, it appears at once that the former are not in many cases joint products. They are usually major products, sometimes

with and sometimes without by-products of value. It is instructive to review the different forms. In the case of palm oil, this is practically the sole product, since the carbohydrate¹ and protein² in the residues left after the extraction of the oil find very little use in the country of origin. In the case of the palm kernel and coconut, these may be crushed in the countries of origin or in countries of destination. When crushed in countries of origin, the residual cake finds little use, except as it may be shipped to other countries for feeding purposes. When crushed in the countries of destination, the cake and meal are used as high-protein feeding stuffs and sell in competition with other high-protein feeding stuffs. In some importing countries, the protein of the oilseeds is so highly prized as a feeding stuff that the oil cake has very considerable value. But if crops be viewed as a whole, the oil of the palm and the fat of the coconut are the principal products, and the carbohydrate and protein of the residues are the by-products. In the case of the soy bean in Asia, on account of the importance of the whole bean in the diet of the common people, it is reasonable to term the fat, the protein, and the carbohydrate co-equal products; when soy beans are crushed in countries of import, however, the fat is the principal product and the cake is the by-product. The same thing holds for the seeds of the peanut, cotton, sunflower, and for the olive—the fats are

¹ Carbohydrate is the term applied by chemists to a group of substances which includes the sugars and substances which when decomposed by hydrolysis (see p. 9) yield sugars. The most important representatives are grape sugar or glucose, fruit sugar, milk sugar, malt sugar, cane or beet sugar, starch, cellulose—which last is the most important constituent of wood, cotton, and many other fibrous plant products.

² Proteins, also known as albumins or albuminous substances, are a class of complex chemical substances present in all living things. They are familiar to everyone for, with water, they are the chief ingredient of the white of eggs, of flesh (muscle tissue), and of blood clots. They are present in milk in roughly about the same proportion as fat (cream) and milk sugar. They always contain carbon, hydrogen, oxygen, nitrogen, usually sulphur, also sometimes phosphorus and iron. Very few of them are soluble in anything but aqueous media. Most of them are coagulated by heating (for example the albumen in white of egg), that is, heat makes them insoluble.

the prime product and the residues the by-product, although cottonseed oil is merely a by-product in the production of cotton and corn oil a by-product in the manufacture of meal and starch.

Quite generally with oil seeds, therefore (cottonseed oil and corn oil being the exceptions), the fats are the chief products and the carbohydrate and protein the by-products, varying under different circumstances from a relatively high value to insignificance. (There is, however, a trend of increase in demand for cake.) When animal and vegetable fats come into competition (for example, tallow and lard versus the several vegetable oils), the animal fats and oils, in themselves secondary products, are competing with vegetable fats and oils, in themselves primary products (except cottonseed and corn oils). Furthermore, in the case of animals, the meat (chief product) is made to carry the load, whereas in the case of oil seeds, the fats and oils (chief products) must carry the load of the commercial operation.

THE QUESTION OF RELATIVE COSTS

Comparison of costs of production of animal and vegetable fats involves numerous complicated problems and cannot profitably be carried beyond a certain point. Certain of the facts bearing on costs are, however, pertinent to the discussion of conditions and trends of production. Fats arise in animals either through the storage of fat ingested with the feed or through the transformation of other feed constituents, of which starch is the most important. These processes are accomplished with losses both of material and of energy, the absolute magnitude of which varies with circumstances. As a matter of fact the losses are very considerable and only a portion, sometimes only a small portion, of the intrinsic caloric values of the feed is recovered as fat and meat in the carcass. From the agricultural or commercial point of view,

the losses incurred when feeding stuffs are converted into carcass fat may or may not represent waste and inefficiency. This depends upon the value of the feeding stuffs and the conditions under which these were produced. If the feed is fit for human food and might have been used for this purpose (as, for example, barley, oats, corn, wheat), or if it was produced upon land that might have been devoted to producing food crops, then the production of carcass fat in this manner might be regarded from one point of view as inefficient, even though it may have been commercially profitable, because the carcass fat and the meat will feed fewer persons than might have been maintained upon the grains used as feed to produce them.¹ If, however, the feed could not have been used as food (for example, straw), or if it was the product of rough land suitable only for pasture, the production of carcass fat may be regarded as a very efficient process, since it converts into food products materials not otherwise of use.

It will be advantageous to illustrate the limited recovery of the calories of nutrients in the flesh of animals raised on them and to indicate the relative preponderance of fat over protein with increasing age of the animals. With good practice in the corn belt in this country, 8 or 9 bushels of corn are required to produce a hundredweight of live hogs, corresponding to a recovery of about a third of the calories of the corn in the form of edible pork. In the feeding of adult steers, the recovery of the calories of corn in the form of beef is often as low as 15 per cent. Possibly 45 per cent in the case of hogs and 30 per cent in the case of cattle represent the maximum limits of practicable recovery of nutrients in the form of edible meat products. To illustrate the preponderance of fat over lean with increasing ages and weights, information may be drawn from analyses of whole carcasses. Hogs weighing

¹ Cf. C. L. Alsberg, "The Effect of Scientific Food Consumption in Increasing Wealth," *Annals of the American Academy of Political and Social Science*, September 1924, CXV, 1-8.

in the neighborhood of 200 pounds will contain something like 24 pounds of protein and 85 pounds of fat, while hogs weighing in the neighborhood of 300 pounds will contain some 30 pounds of protein and 160 pounds of fat. From these data obvious inferences as to what might be termed physiological costs of production may be deduced; but whether physiological costs of production correspond to economic costs of production depends on other circumstances.

Animal fats, then, are not primary products of the soil, they are secondary products. They are produced by feeding primary products of agriculture. The conversion of these primary products, the feeding stuffs, into animal fats is accompanied by heavy losses in nutrients. It is quite otherwise with vegetable fats; these are primary products of the soil, and no such conversion losses are involved. If animal fats were produced only from vegetable fats of the feed one might be justified in concluding off-hand that animal fats are always produced at higher cost than vegetable fats. As a matter of fact they are produced in this manner to a slight extent only. They are produced for the most part by conversion of non-fat material in fodders like alfalfa, hay, straw, stover, bran, and especially from the starch of feed grains. There are still regions where bulky products like fodder and grain have little value because of transportation difficulties, where oilseed crops cannot be made to flourish. In countries like the United States, however, except for range cattle and sheep, animal fat is largely produced from the grains, particularly corn.

Despite the losses involved in converting plant nutrients into animal fats, it is more economical in temperate regions to obtain fats chiefly by this indirect process than directly from plants. This is the case for two reasons. Because meats cannot be produced without the simultaneous production of fat, a large amount of animal fat is

unavoidably produced in the process of obtaining the supplies of meat for which we are willing to pay. A large proportion of this fat would be produced even though it had no more remunerative use than to supply heat for the power plants of the packing houses. Because the fat does have a considerable value, however, it is profitable to produce more than the theoretical minimum per pound of meat. The longer an animal is fed, the larger the proportion of nutrients converted into fat and the smaller the proportion converted into lean meat. With the decrease in value of fat relative to meat in the last generation, it has become necessary to shorten the feeding period and thus reduce the ratio of fat to lean meat in the carcass, but this ratio is still far above the minimum.

The second reason for the relative economy of indirect production of fat, through conversion of plant nutrients into animal fats, in temperate regions, lies in the fact that the plants which thrive in these regions store only small proportions of the nutrients which they elaborate in the forms of fats or oils. They are chiefly fiber- and starch-producing plants. No highly efficient fat-producing plants are adapted to cultivation in most temperate regions. In consequence, vegetable fats can be produced economically in temperate regions only in connection with other joint products capable of carrying the major burden of the costs of production. The necessary conditions are those which account for the existing production of cottonseed and corn oil and to some extent of peanut oil.

With certain tropical plants, however, the situation is otherwise. The coconut and the palm store large quantities of nutrients in the form of fats. They are therefore fairly efficient direct fat producers. With this efficiency, coupled with the fact that they grow in regions where there are no other highly profitable uses for the land, the coconut and the palm are able to compete in fat production with the animals and plants of temperate regions

where the major portion of the costs of production are borne by other joint products.

THE POSITION OF DAIRYING

Dairying is in quite a different position from other forms of animal husbandry, for several reasons. The cow is more efficient in converting feed into human food, in the form of milk, than is the steer or the sheep or even the hog. In addition to milk she produces veal as a by-product and is herself in the end turned into beef when she loses her efficiency as a producer of milk. While the hog stands closest to her in efficiency as a converter of feed into food, she has the great advantage over the hog that she thrives on fodder which is not suitable food for man, whereas much of the diet of hogs must consist largely of grains which are fit for human food. Finally, the dairy cow produces two food elements that are highly prized and therefore high priced. One is protein of high quality; the other is milk fat which in milk, cream, and butter carries a premium price that places it in a class by itself as compared with other fats. Because of its preferred position, butterfat in the United States has not felt as yet to any material degree the competition of the domestic or imported vegetable oils. To be sure there is some competition from the margarins, but unless existing conditions and legislation change greatly it is not likely soon to become much more severe. The consumption of margarin, about two pounds per capita per annum, is small as compared with the consumption of butter, about 20 pounds per capita per annum. Moreover, an appreciable fraction of the margarin consumed is used as a superior cooking fat and here competes rather with animal and vegetable shortenings than with butter.

Dairy farming, then, is in a favorable position because it produces a fat that is so highly prized that it stands to a considerable extent above the competition of other

animal and vegetable fats. In addition it produces protein of the highest quality. Where the dairy farmer is so located that he has a market for whole milk he gets some return for the excellent protein his cows produce.

This is especially the case where there is a market for whole fluid milk as in the neighborhood of towns and cities. Formerly this was the only way the dairyman got much of a return for the protein of milk. Elsewhere milk was paid for on the basis of its butterfat content, for the major use was in the production of butter, the skim milk being wasted or fed to hogs and poultry. Even when milk was used for the making of cheese, which contains most of the protein of milk, the price received was based on the price of butterfat because cheese and butter factories competed with one another.

This situation has begun to change. More and more milk is marketed as whole milk because the percentage of the country's population that is living in towns is increasing and because there is an upward trend in the per capita consumption of fluid whole milk. The development of the condensed and evaporated milk business has a similar influence. But a great effect has come from the development of the powdered milk and concentrated buttermilk business. Buttermilk contains much valuable protein, milk sugar, and mineral salts. Formerly, as already stated, it was fed to hogs and poultry so far as local conditions made possible, and the rest was wasted. Much of such buttermilk is now condensed. The product is concentrated so that it can stand transportation charges; its keeping quality is such that it can be stored. In consequence it finds a wide market as feed, particularly for poultry. Powdered milk is mostly skim-milk powder made from skimmed milk, a by-product in the manufacture of butter. It contains all the valuable food elements of milk except the fat and is an excellent human food. It is widely used by bakers, confectioners, and

chocolate manufacturers. It is saving for human food purposes many millions of pounds of milk protein and sugar that were formerly wasted. As these uses of buttermilk and skim milk grow, the net result ought to be a better return to the dairyman for his milk protein. He can therefore look forward to a steady strengthening of his economic position, and we may look forward not to a decreasing but to an increasing butter production, to be followed perhaps some day by a decline in butter production because of an insistent demand for whole milk.

BEARING OF METHODS OF PRODUCING VEGETABLE FATS

Reference has been made repeatedly to the competition between animal and vegetable fats. It has been pointed out that, irrespective of the relative costs of production of animal and vegetable fats on the same farms, it is more profitable for the farmer in countries like the United States to aim at the production of meat rather than animal fat because of the relatively high price of lean meat as compared with animal fat. It was pointed out further that it is really immaterial in the industrialized temperate zone what the cost of producing vegetable fat is. The competition which animal fats have to face in these regions is not with vegetable fats domestically produced as primary products, but with domestic by-product oils like cottonseed and corn oils and with oils of foreign origin. It is therefore of interest to examine in what manner these competing vegetable fats are produced.

Vegetable fats are the products in part of annual plants, in part of perennial trees. Among the annuals we have cotton, flax, peanuts, soy bean, sesame, rape, sunflower, and corn. Olive and tung trees are grown in orchards; coconut palms and oil palms in groves, some native, some planted. The planting of annuals is adjustable to demand. Trees require time to come into bearing, and have thereafter a varying period of bearing.

In the production of the fats of the palm and coconut there is, so to speak, much more of nature and much less of man than in the production of fats and oils in the temperate zone. Originally palm and coconut fats were secured from native growths and the elements of costs were largely those of labor and transportation. Latterly, plantation development of tropical oil seeds has come to pass, enlarging the producing area. The labor requirements are widely different from those in temperate zones and the labor is of different type. Though some groves are cultivated, for the most part palm nuts and coconuts receive only harvesting and preparation for the market.

The oil-bearing plants of the temperate regions (apart from olive and tung) must be planted, cultivated, and harvested, often when other crops compete for labor. Moreover the labor costs vary widely with the different vegetable oils produced in temperate regions. We lack anything like accurate or comparable cost data for both tropical oils and oils of the temperate zone. Indeed for such by-product oils as cottonseed and corn, joint cost data necessarily would have to be arbitrary. In addition varying transportation costs, greatest for tropical oils, varying costs of extraction from the raw material, and varying costs of refining would need to be included in the calculation. A definite assertion concerning the relative production costs would therefore be unjustifiable. All that is justified, based on methods of production, is that it seems very probable that the outlays incident to production are materially lower for tropical fats than for vegetable fats produced in temperate zones. This finds expression in the decline of oil-seed crop culture in industrialized countries except when it is a by-product like cottonseed or corn oil.¹

¹ Cf. O. E. Baker, "Land Utilization in the United States: Geographical Aspects of the Problem," *Geographical Review*, January 1923, XIII, 24.

RESPONSIVENESS OF PRODUCTION TO PRICE CHANGES

Hitherto in the discussion of the competition between the various fats and oils only factors affecting long-time trends have been mentioned. There are, however, certain differences in methods of production that cause the several fats to react in different ways to abrupt changes in price levels. Production of some fats is more responsive to such stimuli than that of others. Hogs, for example, are more rapidly maturing animals than cattle. Moreover they multiply more rapidly. Any rise in the price of lard can be met more rapidly by increasing the swine population than a rise in the price of tallow can be met by increasing cattle population. Furthermore, for the same reason, the rapid growth of hogs, the lard supply can be increased more rapidly than the beef-tallow supply by feeding the hogs more heavily and marketing them fatter. Indeed, lard in the United States stands in a peculiar position, since together with hog meat it represents a major method of sending corn (maize) to market. The response to any stimulus to increase or diminish the lard supply must therefore be the resultant of at least three factors: the price of lard, the price of corn, and the number of hogs available. The relationships are complex, and will be analyzed in a subsequent study in this series. In the United States, moreover, carcass-fat production is responsive to changes in the general price level of fats to only a limited degree since, as already pointed out, the production of carcass fat under present conditions is not an independent enterprise but incidental to meat production. The response of production to price stimuli must therefore be comparatively feeble. Mutton tallow stands in a somewhat different position from lard and beef fat, for lamb and wool together are the major product of sheep raising and tallow is the by-product. The price of tallow affects the production of mutton tallow far less than do the prices of lambs and wool, indeed scarcely at all.

Among the vegetable fats, cottonseed oil and corn oil are in much the same position as the animal fats, the price of the fat being only a minor factor in determining the production. The production of other vegetable fats, however, is quite sensitive to changes in price levels. Those fats that are obtained from annual crops may be made to increase or diminish in supply by expansion or contraction of acreage. Such fats are linseed, peanut, rapeseed, sesame, sunflower, and soy bean oils. Fats obtained from perennials, usually trees, are naturally not subject to rapid changes in acreage. Trees take too long a period to come into bearing, and once arrived at this state they represent too heavy an investment to be displaced by another crop unless the producer has become convinced that fat production has become indefinitely unprofitable rather than temporarily so. The principal fats from trees are coconut, palm kernel, olive, and tung oils. The supply of these oils varies for one of two causes. In the case of palm, palm kernel, coconut, and perhaps also tung oils, the nuts are simply not gathered if the price is not remunerative. Coconut and oil palms, being tropical trees, are less affected by variations in weather than are oil-yielding plants of the more temperate zones, though of course hurricanes, plant disease, and labor conditions have from time to time some effect upon the potential supply of their fruits. The olive tree, on the other hand, is much influenced by weather conditions and the yield may vary greatly from year to year in any given locality. But the olive yields a superlative oil. The weather also greatly influences the size of the crop of oil seeds from annual plants of the more temperate regions, especially flaxseed.

The weather even influences the production of animal fats, including milk fat, though its influence upon this is perhaps less obvious. The weather determines from season to season the amount of feed available upon pastures and ranges, and this determines the production of milk fat

and the numbers and state of nutrition of beef cattle. The corn crop is the most important single factor in lard production. The weather determines in large measure the size of the corn crop, and thus the weather is indirectly one of the factors that determine the magnitude of production of lard, of butterfat, and of tallow.

Cottonseed oil and corn oil stand in a peculiar position. Cottonseed is a by-product of cotton production. The volume of seed available depends therefore more upon the cotton crop than upon the price of cottonseed oil. But the cotton acreage depends upon the planter's estimate of the probable future price and supply of cotton. The actual production depends upon the acreage and the yield. The yield in turn depends upon the weather, and upon the boll weevil and other insect and fungous enemies of the cotton plant. The quantities of cottonseed available do not depend, therefore, upon the demand for and price of cottonseed oil. The supply may be diminished independently of the cotton crop but not increased. If prices of oil and therefore of seed are very low, farmers may elect not to sell their seed to the oil crushers but to use it for fertilizer or feed. In former decades this was a more important factor than it has been since the United States has ceased to export any considerable quantities of cottonseed oil. The factors that in those days, and to a lesser extent even today, determined whether all or only a fraction of the available cottonseed were to be crushed, were not merely the price of the oil but also the price of fertilizer and of feed, the cake being used for both of these purposes. Cottonseed meal must be fed with caution, but remains a most valuable protein concentrate.

The production of corn oil is relatively small. It is perhaps less affected by the various influences above enumerated than any other fat, for it is a by-product of the corn-products industry and to a lesser extent of the milling of corn meal. The principal articles manufactured

by the corn-products industry are corn starch, dextrine and other adhesives, glucose, so-called gluten feed, corn oil, and a large number of other products of lesser importance used directly or indirectly in the arts. Starch and glucose and, to some extent, dextrine are used as foods, but a large part of the output of the industry is used in the arts. The demand for the majority of industrial corn products therefore tends to fluctuate with the business cycle. The raw material, corn, is always available in abundance for industrial uses, since the industry consumes an insignificant fraction of the crop, though at different prices because the crop varies greatly from year to year. The consumption of corn meal also represents an insignificant portion of the crop. Moreover, from much of the corn ground into meal no oil is produced; the oil-containing fraction of the grain goes to feed. All these are conditions that warrant the conclusion that the quantity of corn from which oil is obtained as a by-product does not fluctuate greatly from year to year. So far as fluctuations do occur they depend primarily upon general business conditions and secondarily upon the price of corn. Hence, unlike cottonseed oil, the supply of corn oil does not fluctuate violently from year to year with the weather, although the trend of production has been upward in harmony with the general expansion of industry and population growth.

V

CONDITIONS AND TRENDS OF CONSUMPTION

In the arts, fats and oils are consumed in a multitude of ways but practically always as such—not as a constituent of some other raw material. In feeding stuffs very great quantities of fats disappear but, with a few unimportant exceptions, they always do so as a constituent of some element of the feed and not as such. Thus the amounts of fat that disappear with grain and legumes fed to animals are truly enormous. In food, as in feeding stuffs, very large quantities of fats are consumed incidentally in the ingestion of meats, fish, poultry, milk, and other animal products and in the form of fats and oils naturally contained in cereals, legumes, fruits, vegetables, and other plant products. However, in the human dietary fats and oils are also consumed practically as such, for example as butter, salad oils, and cooking fats.

QUANTITATIVE DATA UNSATISFACTORY

Not only because fats and oils disappear both in the arts and in the dietary in a vast variety of ways, but for other important reasons, the quantitative study of the consumption of fats and oils encounters great difficulties.

In the first place, the very concept of consumption is elusive. Presumably one should exclude, in spite of its potential significance, the fat content of large numbers of meat animals that perish from natural causes and from which no attempt is made to recover the fats. Commercial consumption is a significant concept, but it excludes a large amount of fats in products that do not enter into trade, and a large amount that are incidental components of meats and other products that do enter into trade, for

example, tankage and garbage. Wastes in the process of recovery are considerable; hence the fat content of the product treated may be considerably greater than the fats recovered as such plus those incidentally retained. The amounts ingested by animals and by human beings would be worth knowing, but they would exclude large quantities that are wasted in various ways on the farms and in households and public eating places. Furthermore, a distinction may be drawn between intermediate and final consumption. Large amounts of fats are contained in cereals, nuts, milk, oil cake, and other products fed to animals; these are in part used up by the animals, and in part are converted or stored up and appear in dairy products or slaughtered animals. Hence a total of the fats consumed by animals and those derived from animals would contain, in effect, considerable duplication.

The difficulties are enhanced by the fact that our statistical information is defective especially in respect to the data on animal fats. For the United States, the number of animals killed in inspected slaughterhouses is known; the total slaughter at wholesale is reported by the census of manufactures (biennial since 1919); but only a guess can be made at the number of animals in other uninspected, principally rural, slaughter. Moreover, there is no clear-cut idea of the fat content per average animal slaughtered; the long-time trend seems to be downward, because younger and lighter animals are coming to slaughter in response to the increasing demand for lamb instead of for mutton, for bacon-type hogs instead of for the lard type, and for baby beef instead of for three- to four-year-old steers. To take even the best ratios derived from packing-house practice and apply them to the total wholesale slaughter of cattle, calves, sheep, and hogs as reported in the biennial censuses, and also to the farm and retail slaughter for which the data are officially admitted to be crude estimates, would be little better than intelli-

gent guessing. There is fairly reliable information on the number of dairy cows and other cows, and it is known that the annual production of milk per animal is rising; but the actual figure of average production is conjectural and the rapidity of increase of outturn indeterminable. Only an intelligent guess at the amount and proportion of total milk fat converted into butter is possible. There are fairly reliable quarterly and annual figures upon the production of vegetable oils. The figures for imports and exports of fats and oils are the best figures available. If, then, one combined the best data and estimates for all forms of fats and oils, the result could hardly be relied upon to give more than a very rough approximation to the total volume available for use (with uncertain allowances for the heavy wastes that are known to occur) and only a rough indication of trend of production.

One might, perhaps, work at the matter backwards. This would mean collecting figures for butter, lard, tallow, packing-house grease, oleo oil, lard oil, stearin, corn oil, peanut oil, soy bean oil, olive oil, cottonseed oil, coconut oil, palm oil, and palm kernel oil as products of specialized industries. Some of these are produced in only a few plants and the figures are accurately reported. The more centralized the production, the fewer the plants; the more perfected the methods, the better the figures. On the other hand, butter production in creameries is less easily measured and farm production of butter is merely a guess.

At the best, there are gaps in the information so large as to make statistical conclusions on several important components, and on fats and oils as a whole, exceedingly unreliable.

It would be of interest to know, for each of the several sources of fats, (1) the amount wasted for lack of any attempt at recovery; (2) the amount ingested; (3) the amount wasted in households and public eating places; (4) the amount fed to animals; and (5) the amount used

in industrial production other than food. We should like these data for fats produced, fats imported, and fats exported. We should like to distinguish between gross and net consumption. Unfortunately, for many of the sources of fats the statistical information is exceedingly defective and it is difficult to reach reliable bases upon which to make the estimates necessary for arriving at supplementary data.

We have made attempts to reach a rough approximation to the amounts of fats and oils available for human consumption or industrial use in the United States in recent years, but at several points gaps are so wide and the procedure is so open to objection that we do not feel justified in presenting here even a preliminary approximation, lest in spite of reservations and qualifications it should be taken for more than it would be worth. In the discussion that follows, therefore, we have incorporated quantitative data only to a very limited extent.

Table 4, however, appears to have sufficient reliability and significance to warrant presentation. It summarizes the annual average consumption (production plus imports less exports or re-exports, in terms of oil or fat content) of the principal vegetable and animal fats in the United States, 1921-25, with certain important and less important exceptions. The two principal items omitted, fat of dressed meats and milk fats (including butter), are so difficult to estimate that we have not included them; yet their sum probably exceeds the sum of the fats and oils here itemized. They go largely into edible uses, except as milk is fed to animals, though in considerable measure meat fats are wasted in the household or subsequently recovered from household wastes for industrial use. The principal other items omitted are fats incidentally consumed in fish, poultry, grains, vegetables, and fruits. Judging from estimates of Raymond Pearl for the period

1911-12 to 1917-18,¹ the sum of these items is probably less than a billion pounds a year, exclusive of the fat in grain fed to cattle. Since most of the fats excluded from the

TABLE 4.—CONSUMPTION OF CERTAIN OILS AND FATS IN THE UNITED STATES, AVERAGE OF ANNUAL FIGURES, 1921-25*
(Million pounds)

Oil or Fat	Average consumption 1921-25
<i>Vegetable—</i>	
Cottonseed	1,074
Coconut	472
Palm kernel	13
Palm	90
Corn	102
Olive	104
Peanut	20
Linseed	654
Chinawood	76
Soy bean	17
Castor	35
Total	2,657
<i>Animal—</i>	
Lard	1,552
Oleo oil, oleostearin, edible tallow.....	147
Inedible tallow	346
Other inedible animal fats.....	364
Total	2,409
<i>Fish—</i>	
Fish oils	134
Grand total	5,200

* Computed from production data published by U.S. Department of Commerce in *Animal and Vegetable Fats and Oils*, 1919-23 and 1924-25, and from foreign trade data in *Commerce and Navigation of the United States*.

table are of animal origin, it is apparent that vegetable oils, despite their large and growing importance, probably constitute less than one-fourth of the total fat and oil consumption in the United States.

¹ *Studies in Human Biology* (Baltimore, Williams & Wilkins, 1924), pp. 388-94.

Of the fats itemized in Table 4, lard ranks first, followed by cottonseed oil and linseed oil, while coconut oil, which before the war was little used, now is in fourth place. Of the vegetable oils consumed as such, about half goes to edible uses, and the other half, including the drying oils, to industrial uses. If it were possible to include all the fats and oils, animal and vegetable, it would probably appear that at least four-fifths of the total net consumption (i.e., exclusive of fats fed to animals) go to edible uses.

For most other countries, in general, the data are even less satisfactory than in the United States.

FATS AND OILS IN THE DIET

The function of fats and oils in the diet is mainly to furnish energy to operate the animal machine. In the body, fats are burned as truly as though they were burned in a candle or under a steam boiler, and the end-products of the combustion are the same—carbon dioxide and water. Moreover, the amount of energy they furnish is the same, namely from 9 to 9.4 calories¹ to the gram, whether they are burned within or outside an animal body. They yield more energy than the other important classes of foodstuffs, such as carbohydrates and protein (albumin),² which furnish from 3.8 to 4.2 calories to the gram.

Neither fats nor carbohydrates ingested are wholly burned at once unless they are needed for the operation of the animal machine. If not so needed, carbohydrates are for the most part completely changed in character by conversion into the fat characteristic of the species. This is stored in the body as a reserve against the possibility of a future period of food shortage. Indeed, most of the fat of domesticated animals is produced from starch. Thus

¹ A large calorie, which is the one here used, is the quantity of heat necessary to warm 1 kilogram of water from 0° Centigrade to 1° Centigrade. A small calorie is the quantity of heat necessary to warm 1 gram of water from 0° Centigrade to 1° Centigrade.

² See explanatory footnotes, p. 50.

the lard of the hogs of the corn belt is mainly derived from the starch of corn (maize). It has the characteristics of fat normal to the animal, is normally stiff, and hence is especially prized. Unlike ingested carbohydrate, the fat of the food, if it is not at once burned, is changed comparatively little. For the most part it is deposited in but slightly modified form with other fat, made by the animal from carbohydrate or protein, in the storehouses for fat—the adipose tissue under the skin, in and about the viscera, and elsewhere. Therefore, if the food fat differs in its properties from the fat natural to the animal and if there is a great deal of it in the feed, the storage fat formed by the deposition of food fat gives an abnormal character to the fat which is obtained from the animal after slaughter. That is why, as stated above (p. 3), the diet may influence the character of the fat obtained from slaughtered animals. This is a matter of practical importance at the present time in sections of the United States where hogs are fattened on peanuts, which contain much oil. The lard obtained from such hogs is abnormally soft and not liked by the consumer. Hence packers are usually willing to purchase such hogs only at a discount.

The dietary fats may be divided into four groups: (1) those consumed as such on the table; (2) those employed in the preparation of foods; (3) those consumed incidentally in the ingestion of meats and other animal products; and (4) those consumed incidentally in cereals, legumes, fruits, and vegetables. The fats consumed as such on the table in the United States are principally butter, butter substitutes (chiefly coconut and oleo oil), and salad oils (principally cottonseed, corn, and olive oils). The fats and oils used in the preparation of food are butter, lard, lard compounds (for the most part cottonseed oil), cottonseed oil as such, corn oil, peanut oil, butter substitutes, and, in certain types of confectionery, coconut oil and cacao butter. Fats and oils consumed incidentally in

the ingestion of meats and dairy products are found principally in milk, cheese, poultry, eggs, beef, mutton and lamb, pork, and fish. The fat of meats is of course to a material extent not ingested but wasted except in so far as it is recovered in garbage and similar greases. The fats of the cereals, legumes, fruits, and vegetables as a class are important in the aggregate nutritionally, but have little direct commercial importance, since few foodstuffs are purchased on the basis of fat content. Practically all foodstuffs except sugar, water, and certain condiments contain some fat. Fresh fruits and vegetables contain merely traces; nuts, on the other hand, are rich in fats, as are also chocolate products. Oat meal and corn meal that is made without removing the germ¹ are relatively rich in fat; wheat flour is poorer. According to Pearl,² the incidental fat ingested in the form of cereals, vegetables, fruit, nuts, fish, poultry, and eggs amounts to 16-18 grams³ per capita per day.

A study of the trends of consumption encounters the difficulty that statistics of fat in the diet over a series of decades are not available. Certain inferences seem nevertheless warranted. Trends of consumption may be grouped in two classes according as they are due primarily to changes in habits or primarily to substitutions made by manufacturers of which the consumer may or may not be aware. The two classes of course overlap, for in certain cases both factors play a part. Thus a manufacturer may create a new product which leads to a new food habit or, *vice versa*, consumer demand may lead to substitution or creation of a new product by the manufacturer.

¹ This type of corn meal is sometimes known as "old-fashioned" or "water-ground" corn meal because it was the only type made in former times when water power was the commonest motive power for American mills. It does not keep well, for it turns rancid easily.

² Raymond Pearl, *The Nation's Food* (Philadelphia and London, Saunders, 1920).

³ A little more than half an ounce.

INFLUENCE OF CHANGES IN FOOD HABITS

Change of food habits may be of two sorts. It may be purely quantitative or it may be qualitative. By a quantitative change is meant increase or decrease in consumption of a given fat rather than the substitution in the diet of one fat for another. By qualitative change is meant primarily a substitution of one fat for another. However, since for physiological reasons the intake of food is practically constant for any individual under any given set of circumstances, a decrease in fat ingestion usually involves either a substitution for it of some other kind of food, or of some other kind of fat. Conversely, an increase usually involves a decrease in consumption of some other kind of food or of fat. Since all fats and oils have very nearly the same food value,¹ one can be substituted for another without change in the volume of food ingested. However, if another food be substituted, the volume of the diet is thereby necessarily increased since no other food has, weight for weight, so great an energy value (see p. 68). It follows that if the replacement of fat in the diet by other foods goes too far the diet must become very bulky if it is still to furnish the same energy value, and this fact sets mechanical limits to the substitution of other foodstuffs for fat in the diet.

Since the caloric requirements of an individual, as stated above, are constant under given conditions, it follows that under these circumstances a reduction in consumption of a fat involves the substitution for it of either an equal amount of some other fat or a corresponding amount of some other foodstuffs. But conditions do not remain constant for any person. He grows old and re-

¹ This statement applies to energy values. Certain fats contain small quantities of chemical substances of unknown chemical nature but of great importance to health. These are known as vitamins or food accessories. Different fats contain different amounts of them depending upon their origin, method of preparation, and other factors. From the point of view of their vitamin content all fats are not of equal nutritive value; but these are considerations not discussed here.

quires less food. He may become stouter or leaner, then consuming either more or less food. He may change his means of livelihood from one requiring hard manual labor involving high food requirements to a sedentary occupation requiring a low food intake. He may migrate from a very cold climate where food requirements are relatively high to a hot one where they are relatively low. In any nation all these changes are taking place in some individuals in one direction, in others in the opposite direction. For short periods, the result is a reasonably constant consumption.

Over a long period of time this is no longer true. The age distribution of populations changes. If the birth-rate falls and the average span of life lengthens, the proportion of old people who consume little food increases, the proportion of young people who consume much decreases. If it becomes unfashionable to be stout, less food is consumed by the nation as a whole. If the proportion of manual laborers becomes less and that of machine tenders and sedentary workers greater, the per capita consumption of food tends to fall. Since fat is the most concentrated form of food energy, its intake tends to be reduced rather more than that of other forms of food.

In the United States exactly these changes have been taking place for decades; and there is evidence of a corresponding decline in the nutritional use of fats and oils, as part of a general reduction in the per capita food requirements. This reduction is the result of substitution of machine labor for man labor, the decline of outdoor employment in severe winter weather, the improved heating of buildings, the trend to lower average body weights of the people generally, and changes in the age distribution of the population. The population is acquiring more sedentary characteristics, needs less food, and the average per capita requirements of foodstuffs in terms of calories are automatically reduced. Most of these factors are the

result of the economic evolution of the country and in essence reflect improvement in the standard of living.

The rise of the standard of living is responsible for certain other changes in food habits. It results in a diversification of the diet with increase in the use of dairy products, fruit, vegetables, and sugar, and decline in the ingestion of cereals and fats.¹ This general statement does not hold for the fat of milk, the use of which is on the increase. Fat consumed incidentally to the ingestion of meats and dairy products has always been heavy. The consumption of milk and poultry fat is increasing, that of beef, sheep, and hog fats is declining. Plain cooking is being replaced by more fancy cooking, which includes more discriminating culinary uses of fats and oils. American practice has departed from the British custom of boiling vegetables without fat. Much of the crackers and bakers' bread consumed now contains shortening. The increased consumption of sugar has carried with it enlarged use of shortening agents. At the table the use of butter as a spreading material is on the increase. The wider use of fresh fruits and vegetables has resulted in greater consumption of salads, which in turn has increased the use of salad oils.

These facts might seem to suggest increased use of fats and oils. A survey of the entire field, however, suggests that the net result is a lower per capita ingestion of fats in general. The heavy fat rations of hard workers are a thing of the past—fat-backs and sow-belly are no longer staples. We use more butter, but less hog fat. The current public taste for younger and lighter-weight animals represents a substantial reduction in fat. It seems fair to infer that, milk fat and poultry fat aside, the decline in the ingestion of fats applies to animal fats. Over a generation, indeed, it is possible that there may have

¹ Cf. *The Decline in Per Capita Consumption of Flour in the United States*, WHEAT STUDIES OF THE FOOD RESEARCH INSTITUTE, July 1926, II, 265-92.

been an absolute increase in the per capita consumption of vegetable oils with an absolute decline in the per capita consumption of animal fats outside of milk fat.

INFLUENCE OF CHANGES IN FOOD MANUFACTURE

The changes in trends of food-fat consumption are not all by any means due solely to change in habits. Some of those that are quantitatively extremely important are due to substitutions on the initiative of manufacturers of food-fat preparations—for example, the substitution of lard compounds for lard—or to the increasing availability of new types of fat—for example, coconut oil. Some of the possibilities of substitution in food uses have already been touched upon incidentally. However, since dietary consumption is the major and the higher or premium use of fats, the practice and possibility of substitution require elaboration because they are basic to any consideration of the commodity economics of this important group of raw materials. The substitution of one fat for another, indeed the mere possibility of such substitution, naturally has the greatest influence upon prices. Given sufficient price inducement, one fat may in some cases displace another with the widest repercussions upon the producer, the farmer, the trader, and the manufacturer. It is one of the purposes of the *FAT AND OIL STUDIES OF THE FOOD RESEARCH INSTITUTE* to present studies from time to time upon far-reaching movements of this general character.

That considerations of price, costs of conversion and refining, lack of technological skill, and legislation in the interests of public health and sanitation limit the volume of inedible fats turned to edible uses, has already been pointed out. But there are other factors as well that limit not merely the diversion of inedible fats to edible uses but also the substitution of one edible fat for another. The most prominent of these are greater or lesser adaptability of different fats to use in the preparation of different

foodstuffs, and psychological and sentimental factors that in the food industries play a greater part than in the arts.

DEVELOPMENT OF LARD COMPOUNDS AND MARGARIN

The degree of adaptability of fats to different culinary practices is a result of their physical behaviors (consistency, flavor, etc.), not of their nutritive properties. It is the constant effort of technologists to widen the adaptability of fats to different uses. One of the more notable of their achievements is the production of lard compounds, as a result of which the use of lard seems relatively declining,¹ that of lard substitutes increasing. And there has also been a pronounced decline in the use of tallows as cooking fats in the factory and the home. The principal use of lard is as a shortening and cooking fat. In the United States lard compounds are substituted for it in these uses to a considerable degree. This means the substitution of beef stearin and cottonseed oil (hydrogenated as well as unmodified) for lard (see p. 42). This very extensive substitution has been possible partly because lard compound is a very good imitation of lard, partly because there is no adverse legislation;² but also because sentimental considerations on the part of the consumer favor rather than hinder the substitution. Lard compounds usually lack the flavor of lard. They are for the most part quite bland, and this lack of distinctive flavor causes them to be preferred by a considerable portion of the population. Many brands of lard compound are made wholly from vegetable oil. They contain no animal fat whatever. The manufacturers have been clever enough to feature this fact and thus to appeal to that portion of the population

¹ The lard production figures of the U.S. Bureau of Animal Industry cannot be used to controvert this view. It may well be that the per capita consumption of lard is increasing absolutely, while decreasing relative to lard substitutes. Also, it may well be that the per capita consumption of lard is increasing while the per capita consumption of hog fat is decreasing, owing to diminished use of salt pork and other fat cuts.

² Such legislation was proposed in Congress around 1890.

that assumes the vegetable fats to be purer, cleaner products than animal fats. Indeed, manufacturers have gone so far as not to represent their products as lard substitutes at all but as vegetable shortenings, sold commonly under their own distinctive brand names.

Manufacturers of margarin, the other notable achievement of technologists in the food-fat preparation field, have not been equally successful. This is due in part to psychological and esthetic considerations (taste, color, spreading qualities). Against esthetic and sentimental factors successful substitution is difficult. Success demands that the substitute be a nearly perfect imitation. Margarin manufacturers have not always been wholly successful in making their product resemble butter exactly—no doubt in part due to adverse legislation. Within the industry itself there has been a drift from animal fats as raw materials to vegetable fats—especially coconut, cottonseed, and peanut oils. The use of peanut oil continues in the face of the competition of cottonseed oil because of the legal requirement that margarins represented to the consumer as being nut products must be made of nut oils. Peanuts are classed by botanists as nuts whereas cottonseed is not.

The drift of the production of margarin predominantly from animal fats to its production predominantly from vegetable oils is shown by Table 5, giving the production of oleomargarin in the United States from 1918 to 1926. In the latter year that made exclusively from vegetable oils slightly exceeded all other kinds.

The table shows that margarin made exclusively from animal fat is now so scarce as to be almost negligible from a statistical standpoint. The all-vegetable product amounted to 116 million pounds in 1926, while the mixed animal and vegetable product was somewhat less. In this country there is a tax of 10 cents a pound on colored margarin and consequently its output is small, although it

has averaged somewhat more than 10 million pounds during the more recent years.

Accompanying this drift toward greater use of vegetable oils in margarin is a largely increased use of coco-

TABLE 5.—PRODUCTION OF OLEOMARGARIN IN THE UNITED STATES, CALENDAR YEARS, 1918-26*

(Thousand pounds)

Year	Uncolored: made of			Colored: made of			Total
	Animal and vegetable oil	Exclusively vegetable oil	Exclusively animal oil	Animal and vegetable oil	Exclusively vegetable oil	Exclusively animal oil	
1918.....	255,197	88,862	3,307	7,056	112	1,003	355,537
1919.....	214,759	132,906	3,391	9,303	9,793	1,165	371,317
1920.....	161,636	190,280	3,843	8,951	5,359	94	370,163
1921.....	103,962	99,265	624	5,960	2,026	30	211,867
1922.....	104,285	74,127	303	4,976	1,384	1	185,076
1923.....	121,271	93,970	450	7,078	2,808	0	225,577
1924.....	119,641	97,871	413	7,847	3,259	0	229,031
1925.....	109,588	108,490	74	8,243	4,215	0	230,611
1926.....	108,871	116,215	0	8,574	4,934	0	238,594

* Data from *Agriculture Yearbook, 1926*, p. 1086, and *Crops and Markets*, August 1927, p. 313.

nut oils, at least in the United States. This is shown by Table 6 (p. 78). An examination of this table shows that coconut oil in recent years has been more important than oleo oil and neutral lard together, accounting for 41 per cent of the total consumption of fats and oils in margarin. In 1912 a negligible quantity of coconut oil was used, while in 1926 (fiscal year ending June 30) its consumption had grown to 98 million pounds. Cottonseed oil and peanut oil were the other most important vegetable oils used.

Neutral lard and peanut oil are the most expensive of the products that ordinarily go into margarin in any considerable quantity; accordingly, in case of a general price advance, their use is most likely to be curtailed. Oleo oil is practically always cheaper than neutral lard, but as a regular thing higher than coconut or cottonseed oil. When

the cotton crop is large, cottonseed oil is cheaper than any other ingredient; when it is small, coconut oil is usually cheaper. Its relatively low price has undoubtedly been the most important reason for its increasing use.

TABLE 6.—CONSUMPTION OF FATS AND OILS IN THE MANUFACTURE OF MARGARIN IN THE UNITED STATES, AVERAGES OF DATA FOR FISCAL YEARS ENDING JUNE 30, 1912, 1914, 1916, AND 1922-26*

(Thousand pounds)

Fat or Oil	1912-14-16	1922-26
<i>Vegetable fats and oils—</i>		
Cottonseed	29,666	20,278
Coconut	323	76,773
Peanut	3,642	6,770
Other	1,401	1,240
<i>Animal fats and oils—</i>		
Lard	22,560	27,936
Oleostearin	1,854	5,054
Oleo oil	47,860	46,282
Oleo stock	217	2,697
Other	1,833	4,143
<i>Unidentified as to origin—</i>		
Total	109,356	191,859

* Data from U.S. Tariff Commission, *Certain Vegetable Oils, Part 2, 1926*, and *Annual Reports of the Commissioner of Internal Revenue, 1925 and 1926*.

Only a portion of the margarin produced is used as a substitute for table butter. Other very important uses are in the making of bakers' cake and pastry. Cake margarin ordinarily has a slightly lower melting point than table margarin, while pastry margarin on the other hand has a distinctly higher melting point. It is apparently not the universal practice to use milk (see p. 42) in the manufacture of these latter types of margarin. Otherwise the ingredients are similar to those going into table margarin, except that in the case of pastry margarin higher-melting-

point fats are substituted for the lower ones, for example, oleostearin for oleo oil, and, at least in Europe, hydrogenated fish oils are also used.

SUBSTITUTION IN OTHER FOOD USES

Restrictive legislation, an important influence in margarin manufacture, is also completely preventing substitutions in other foodstuffs. The manufacture of filled milk is prohibited, and the manufacture of filled cheese has been taxed practically out of existence. Filled milk is skim milk in which coconut oil has been emulsified—in other words, it is milk in which the natural fat has been replaced by coconut oil. Filled cheese is made from skim milk and some fat foreign to milk or from partly skimmed milk and such fat.

Ice cream is another product in which expensive milk fat might be replaced by a cheaper one—for example, coconut oil. This substitution is not generally permitted by food-control officials, though it is reported that such a product is sometimes made for purely local consumption.

In the confectionery industry there are similar possibilities of substitution. Chocolate is made from the cacao bean¹ by first roasting in revolving steel cylinders, after which the hulls are removed by machinery. The beans are then crushed and freed from the germs. The coarsely crushed product, freed from hulls and germs, is known as cacao nibs. The nibs, finally, are thoroughly ground between stones, the material being reduced to a thin paste which, on cooling, sets to a firm cake. It is known as unsweetened or plain chocolate. It contains over 50 per cent of cacao fat, which is known as cacao butter. It is produced from chocolate by expression, and is a soft solid

¹Not to be confused with the coconut. The cacao bean is the seed of *Theobroma cacao*, L., a tree native to Central America but grown commercially in many places in the tropics. The seeds are borne in large pulpy fruits, each about 10 inches long and 4 inches thick and containing from 20 to 40 seeds. The coconut, on the other hand, is a true nut produced by a palm, *Cocos nucifera*, L.

much prized for certain uses in pharmacy. The press-cake that remains is known as cocoa or, when ground up, as powdered cocoa.

Many kinds of confections are coated with chocolate. They are made by dipping the center into a melted mixture of chocolate and sugar. If much sugar has to be added to the chocolate coating to give it the desired sweetness, it is necessary to add cacao butter in order that the melted mass may be sufficiently liquid. It would be perfectly feasible to substitute for the expensive cacao butter a cheaper fat such as coconut oil. The addition of such a fat with its higher melting point would, moreover, be advantageous because the candies would be less likely to become soft, sticky, and unsalable in warm weather. It has been held that the use of a fat other than cacao butter is not permissible if the confections are to be sold as chocolates, for the consumer would be deceived into believing that he was receiving a product made solely from the cacao bean with, of course, sugar, etc. In the case of confections not so sold but offered for sale under some fancy distinctive name the use of coconut oil is permitted. These are mostly cheap products sold by the unit for a nickel or a dime. Coconut oil may also be used in frozen products of the type of Eskimo Pie. Owing to the need for using additional cacao butter in products sold as chocolates it often happens that when the price of cacao beans is very low cacao butter is produced without any cocoa as a by-product. The beans, hulls and all, are simply run through an expeller to extract the butter while the press-cake, which contains all the cocoa, is used as fuel or thrown away.

In short, the trends in the use of fats in dietary uses may be summarized thus: The per capita use of fat as a fuel, a staple, has declined. Fats and oils are used in more specialized states, more discriminatingly, in our present

diversified diet. Substitutions are widely practiced, but they are less varied and diverse than in the arts, partly because more stringent demands are made by the consumer in regard to the adaptability of a given fat to a particular culinary use, partly because of esthetic and sentimental considerations, and finally because of legislative restraints.

FATS AND OILS IN THE ARTS

The preparation of fats for food uses is on the whole comparatively simple. The use of fats in the arts involves in many cases intricate, complicated, and multiple manufacturing processes. Many of these processes are secret—at least when first introduced. In consequence, in studying consumption and trends of consumption in industry all the difficulties of studying consumption of edible fats are encountered and in addition many others. Changes are more rapid, as well as less easily recognized, than in the food field. Yet since many fats can be used either in food production or in the arts, the trends of consumption of one class of fats cannot be understood without knowledge concerning the other.

In many directions, the industrial uses of fats and oils have been expanded through technological improvements; in a few directions there has been contraction. The increased use of soap and cleansing materials is one of the characteristics of our times. Indeed, the per capita use of saponaceous materials is almost an index of civilization, considered either from the sanitary, the hygienic, or the esthetic point of view. The consumption of soap in the United States reached 1,189 million pounds in 1925.

The principal materials used in soap making in this country, as reported by the Tariff Commission,¹ in the order of their importance in the years 1921-23 were:

¹ See U.S. Tariff Commission, *Certain Vegetable Oils, Part 2*, p. 168. The latest year covered in this investigation was 1923.

1. Inedible tallow
2. Coconut oil
3. Other inedible animal fats, such as greases and fish oils
4. Cottonseed oil and foots
5. Palm oil
6. Olive oil and foots
7. Other vegetable oils

Tallow is consistently, year after year, the principal ingredient. Coconut oil, which is second to tallow in importance, has increased in recent years far more rapidly than any other ingredient except palm oil. The consumption was over 250 million pounds in 1923. Before the war a certain amount of palm kernel oil from British colonies in West Africa was imported into the United States, but during the war and until 1925 this trade was diverted and little was received here. Recently—i.e., in 1925 and 1926—American imports have increased again and palm kernel oil has doubtless been substituted to some extent for coconut oil, which it closely resembles.

In most years cottonseed oil is not an important ingredient of soap, but "foots" (see p. 30) are used to a more important extent. Both commodities have diminished in importance during the period that coconut oil has been increasing. The principal reason cottonseed oil is not used in greater volume is that it brings a better price in the edible-oil market and consequently, unless there is ample surplus, the bulk of it goes to edible uses. Foots, on the contrary, can only be used for soap or be distilled for their fatty-acid content. The various grades of greases are also used in soap; and the volume so used may have increased materially, perhaps keeping pace with the rapidly increasing production of grease and the striking recent development of the rendering industry.

Ordinarily coconut oil is more expensive than the other fats used in considerable volume in soap. Its special characteristics give it a premium over other materials. Tal-

low, white grease, and palm oil are ordinarily about the same price, although palm oil is apt to be cheaper than the other two and white grease at times is far higher, probably because it is now and then wanted in European markets as a substitute or adulterant for lard.

There has also been a greatly increased use of oils and fats in the manufacture of linoleums, artificial leathers, rubber substitutes, and a host of specialized products.

Economies have been introduced in the use of oils in tin plating and in the manufacture of woolen cloth. Undoubtedly, the use of vegetable oils as illuminants is declining to the vanishing point. The vegetable- or animal-oil lamp and the tallow candle have ceased to exist in households, except for special occasions. There is, of course, a small persisting use of oils as illuminants for sacramental purposes, and there is quite a material use of fats for stearic-acid candles. To some extent, stearic acid is being replaced by paraffin. With the decline in number of work animals has come reduction in need for harness dressings. The relative use of fats and oils as belt dressing has probably declined, though the absolute quantity may have increased. In pharmacy, with the exception of cacao butter, fats have been replaced in ointments and salves by petrolatum and lanolin (wool grease).

The position of fats and oils as lubricants is difficult to determine. The amount of lubricants used has, of course, expanded enormously; but in this expansion animal and vegetable fats and oils have shared relatively much less than lubricants derived from petroleum. The absolute quantities of animal and vegetable fats and oils used in lubricants may not, however, have been reduced (indeed, an increase may have occurred), even though their proportion in the total mass of lubricants has been substantially lowered. Large amounts of animal and vegetable fats and oils are being used mixed with mineral oils in the preparation of special lubricants. Most of the manufac-

turers of lubricants use secret formulas, and it is not possible to learn what is the trend in these directions.

In estimating the trend of the use of animal and vegetable fats and oils in paints, difficulties are again encountered. The proportion of wooden buildings, requiring exterior painting, is declining relative to buildings constructed of other materials and requiring little exterior painting. For many of the coarser and cheaper paintings mineral substances are being widely used. In the treatment of floors, waxes are rapidly replacing paints. For interior household painting, and for high-grade painting and varnishing in general, the drying oils held their place until the advent of plastics derived from cellulose. These have practically replaced paint and varnish on new automobiles and are making heavy inroads with furniture, railway cars, refrigerators, and for interior uses in rooms such as kitchens and bathrooms. To what extent the application of these plastics may be so cheapened as further to encroach upon paints prepared with drying oils, remains to be seen.

SPECIAL DEMANDS FOR PECULIAR PROPERTIES

The several fats and oils have many properties in common; but some of them possess peculiar qualities. It follows that they are both complementary and substitutable. When a particular fat has unique properties, the commercial use will be inelastic to some extent. When a particular fat has only properties common to them all, the commercial use is elastic. In so far as fats have peculiar properties, there is a range of uses within which they are not substitutable, where competition between them is subordinate. In the range within which fats and oils have properties in common and are substitutable, competition is predominant. Fats possessing peculiar properties carry a premium, within limits; fats possessing only common properties compete with each other on a

close margin. The long list of commercial fats and oils represents a series of overlapping raw materials, with ascending prices in proportion to their peculiar properties or particular desirabilities. The lowest reclaimed grease stands at the bottom; at the top stands unsalted butter. The technologist is continuously endeavoring to enlarge the list and range of substitutable uses and to narrow the list of premium uses.

A few illustrations will make the commercial situation clear. The outstanding drying fats are linseed and tung oils, and for certain of the most particular paint and varnish uses they stand alone. But in the manufacture of common paints, it is practicable to add a proportion of semi-drying oils such as soy bean and fish oil. For the finest paints and varnishes the demand for linseed and tung oils is inelastic; for the commoner paints, the demand is elastic. There is little price competition from the other fats at the top, but sharp price competition at the bottom. Linseed oil is an edible oil, but it is too valuable as a drying oil to serve as an edible oil in the United States, quality considered. The drying oils cannot be used as lubricants.

Candles are made from stearic acid. In the manufacture of candles, therefore, fats containing a high proportion of tristearin must be sought out, or else triolein must be converted into tristearin through hydrogenation, which is usually too expensive to be practicable. This tends to give a certain priority in this use to fats containing a high proportion of stearic acid, and such fats are commonly purchased on the basis of the titre test (see p. 19), by which the content of stearic acid is judged. This applies particularly to superfine hard candles; for the commoner candles, softer fats and paraffins are substitutable.

SUBSTITUTABILITY IN SOAP MAKING

Tallow is regarded as one of the fats most desirable for soap because it yields a soap that is both hard and

of good color. It has gradually come to be displaced to a certain extent by other fats so that at present little if any soap is produced from tallow alone. It is practically always blended with other fats, partly because of price considerations, but perhaps even more largely because better soap can be made from such blends than from tallow alone. While tallow soap gives a good and lasting lather, it dissolves rather slowly and so lathers slowly. This is remedied by adding other fats which yield soaps that dissolve more quickly and so lather more easily. A number of oils are used for this purpose, but especially coconut oil, which has the further advantage of retaining a large proportion of water in the soap, thereby increasing the soap makers' yields. Soap containing coconut oil is more soluble in salt water than most other soaps except palm kernel oil soap. It therefore lathers in sea water; hence coconut oil is used in so-called marine soaps. Palm kernel oil soap has properties very similar to those of coconut oil soap and may be used for the same purposes. In the United States this oil is relatively little used, but in Europe it is very largely employed interchangeably with coconut oil. Coconut oil, moreover, is especially valuable in soap chips because its soap, while hard and brittle, is very soluble. The washing machine has created a wide demand for such soap chips. Coconut and palm kernel oils occupy a premier position in the manufacture of marine soaps and laundry chips. For these uses other fats cannot be substituted for them, though both oils can be substituted for other fats over a wide range of other uses.

There is a wide range of adaptation in the manufacture of toilet, laundry, and household soaps. In these, a number of animal fats and vegetable oils are substitutable, under technological procedures, largely on the basis of price. Manufacturers of trade-mark soaps endeavor to keep them uniform in order to retain established markets. There is a certain range within which they can substitute

the raw materials and still maintain uniformity in the soap, and within this range they purchase the raw materials on the basis of price. Outside of this range they cannot substitute fats with maintenance of uniformity, but must buy certain fats at going prices. The properties of trade-mark toilet soaps are held more rigid and invariable than those of trade-mark household and laundry soaps. The properties of trade-mark household and laundry soaps are held more rigid than in the case of soaps not carrying trade-marks. The lower the usage, the less the necessity for uniformity. Under these circumstances, the range of substitution varies inversely with the price of a soap. Since common soaps are manufactured on a price basis, soap makers under efficient technological practices draw their raw material from every conceivable vegetable and animal source. Indeed, they sometimes substitute other raw materials for fats and oils.

Thus in yellow laundry soap there is a good deal of rosin if the price warrants. Rosin acids form sodium salts which are freely soluble in warm water, lather well, and have good cleansing action. Rosin, however, is not used in white soaps; it makes them not merely yellow but also sticky. Hence also, it is not used in soap chips. Besides rosin, a variety of other substances are used at times, some of which are merely fillers or adulterants. The commonest is sodium silicate, familiarly known as water glass, of which as much as 20 per cent of the weight of the soap is sometimes used. Opinions differ as to whether this is to be regarded merely as a filler and make-weight or as a useful ingredient. Indeed, the substitution of other materials for fats and oils in many directions has been the endeavor of chemists for some time with considerable success, especially in the substitution of mineral products for fats and oils in lubricants, and of new types of varnishes and lacquers, free from vegetable oil, for the older types in which drying oils serve as the medium. Of course,

such substitutions are not possible in the edible field, in which substitution is limited to one fat for another.

The uses of coconut oil are of interest in this connection. It is widely used in soap, especially marine soap, and in margarin. It is, however, a poor lubricant, and compounds containing a large proportion foam badly when used for deep frying. Coconut oil is therefore a premium material for marine soap, an available material for common soap, but not to any important degree available for lard compounds or for lubricants.

CONCLUSION

Taking the situation as a whole, about all that can be said in the absence of more adequate statistics is that the trend of per capita consumption of fats and oils is probably on the increase, owing largely to increasing consumption of soap. Probably per capita consumption for food is somewhat decreasing. In industry, aside from soap, per capita use is possibly decreasing because of substitution of petroleum and synthetic products, though it is not improbable that the total amount of fats and oils consumed in industry outside of soap factories is increasing due to population growth. What the exact quantitative relations are, it is at present impossible to estimate.

VI

INTERNATIONAL TRADE IN FATS AND OILS

Fats and oils figure heavily in international trade; in particular the volume of trade in oil nuts, oilseeds, and vegetable oils has increased with the exploitation of tropical sources of supply, the development of technology, and the relative decline in animal fats.

Although statistics of international trade in fats and oils are less inadequate than statistics of production and consumption, they are far from satisfactory and present so many difficulties that no summary presentation seems desirable at present.¹ In subsequent studies of particular commodities the current position and the trends can be set forth in some detail with appropriate qualifications and reservations. Here, however, it is desirable to present only a broad and more or less provisional statement, with comparatively little quantitative data.

THE INTERNATIONAL POSITION IN GENERAL

The international trade in fats and oils flows largely in a few prominent streams. Palm and palm kernel oils come chiefly from Africa, though the Dutch East Indies are beginning to enter upon this trade. Practically all soy bean oil comes from Asia. Peanut, rapeseed, and cottonseed oils come from several regions. Coconut oil comes largely from the Philippines, the Dutch and British East Indies, and Oceania. Large amounts of cattle and sheep fats come from Australasia and Argentina. The United States and the lower Danubian area are practically the

¹ A useful recent summary is given by the U.S. Department of Agriculture in "The World Situation in Oils and Oilseeds," *Foreign Crops and Markets*, May 9, 1927, XIV, 594-647.

sole exporters of lard. Imports are much less specialized than exports, though many countries import predominantly more of one fat or oil than of others, depending on political affiliations.

By and large, the more backward regions are prominent as exporters, while the highly civilized regions are prominent as importers. This is due partly to fundamental conditions affecting production, partly to considerations affecting consumption. But many countries export some fats and oils and import others, so that their net position in international trade in fats and oils as a whole may be very different from their position with respect to any one. Broadly speaking, Africa, Asia, and Russia are net exporting regions, while Europe and North America are net importing regions.

The term self-sufficiency, frequently used in this connection, may mean something or little, or may be actually misleading. It is technically correct, for example, but essentially misleading to say that the United States is not self-sufficient in cotton. We import each year some 200,000–500,000 bales, but our annual exports average well over 6 million bales. Cotton is not a unity. The imports consist largely of certain kinds that the United States does not produce at all. The cotton imported could, however, be produced, but the cost would be excessive. In view of the manifold sources and uses of fats and oils, it might similarly be misleading to say that any country, merely because it imports fats and oils, is not self-sufficient in these products. Import requirements and exportable surpluses are often not a matter of rigid need or absolute excess, but are evidences of adaptation, substitution, and price relations.

In the analysis of the international position of a country, the position as net exporter or net importer may or may not be significant. To be a net importer may signify a shortage, irrespective of price; thus the United States

is a net importer of nickel because it has no deposits. But a country may be a net importer solely on the basis of price; the United States is a net importer of paper, not because it lacks the resources in its forests, but because at present the forests of Canada furnish a cheaper product. A country may be a net exporter because of the position of a primary industry; in this sense, the United States is a net exporter of copper. But a country may be a net exporter for incidental reasons; thus the United States is a net exporter of caustic soda.

For some countries it is difficult or impossible statistically to determine whether they are net importers or net exporters of fats and oils. Also, if this be ascertained, it may be difficult or impossible to determine whether the position is inherently necessary or merely incidental. A determination of the net position of a country in respect to fats and oils is particularly difficult because of the complexity of the situation, one manifestation of which is the inadequacy of statistics. Fats and oils pass in and go out not only as such, but under other names and in other forms. The United States both imports and exports fats and oils for use in the manufacture of soaps; it also both imports and exports soaps. Lard is counted as an export of fat, while cured-pork products are not; yet backs, sides, and bacon are three-fourths fat, and hams and shoulders are one-third fat. A state may be a fat-importing country when considered from the standpoint of industrial fats, and a fat-exporting country when considered from the standpoint of dietary fats; this is the position of the United States. It is, therefore, likely to be misleading to judge of the position of a country in respect to its total uses of fats and oils solely by such a classification as net importer or net exporter as might be determined from the use of trade statistics. Let us consider the circumstances in different countries.

THE POSITION OF PARTICULAR COUNTRIES AND REGIONS

Russia, before the war, was a heavy exporter of butter, linseed oil, and edible vegetable oils. The customary diet of Russia was poor in fats and meats, consisting predominantly of cereals and vegetables (mostly rye, cabbage, and beets). Because of a low standard of living, the industrial uses of oils and fats were limited. On the basis of the trade figures, Russia was self-sufficient; but she was so only because the uses of fats and oils in that country occupied a position so low, in contrast with that of western European countries, as to seem abnormal.

The position of Russia is just the opposite from that of the United States. The two countries are not incomparable in size, population, and agricultural resources. Russia could not be called a superior fat producer and the United States an inferior fat producer. But Russia, in contrast with America, has a low standard of living, in respect to both dietary and industrial uses of fats and oils. Russia is a net exporter of fats and oils, but could easily consume what she exports if she were not a backward country; the United States is a net importer of fats and oils, but could easily produce more if she chose.

Europe as a continent, outside of Russia, is a heavy net importer of fats and oils, although a few countries, such as Denmark, are net exporters. Oilseeds are imported both for the protein and the oil fractions. The continent is also a heavy net importer of meats and animal fats, though Denmark and the lower Danubian area are net exporters of animal fats. The population of Europe is dense in respect to the agricultural area; and most countries are highly industrialized. Cereals, meats, animal fats and oils, vegetable fats and oils, must be imported. More could be produced of any one of these; the amounts that are domestically produced at any time largely determine the amounts to be imported. The adjustment between the different types of agriculture and

the different imports of foodstuffs and industrial raw materials is mainly the expression of current efficiencies in agricultural technique, within the limits set by climatic factors and character of soil.

The United States is a net exporter of animal fats. It is a large net exporter of hog fats, both in the state of lard and in cured-pork products. In much smaller but still considerable amounts, it is a net exporter of beef fats in various forms. On the other hand, the import of live cattle is fairly extensive; and imports of milk fat, chiefly as butter, generally exceed exports.

The United States is a substantial net importer of vegetable oils. Cottonseed oil is the only one of which the exports are appreciable, and most of the exports of other vegetable oils are either small in amount, or are produced from imported materials, or are re-exports of oils of foreign origin. Practically all kinds of vegetable oils are imported, either as such or, much more largely, in the form of raw material. Imports of linseed oil (chiefly in flaxseed) and coconut oil (chiefly in copra) are the largest items, but imports of olive, palm, palm kernel, china-wood, and castor oil are also important, and several other kinds are by no means negligible.

The picture is heterogeneous. If all the imports and exports were lumped, the United States would be shown to be a net importer, to a small extent per capita. But that the country is a net importer does not mean that there is a shortage, in the sense of inability to supply needs from domestic production. It merely means that a small fraction of our heavy fat and oil requirements is imported because it is cheaper to secure it thus than to produce it. If one separates dietary from industrial uses, the country is a net exporter of dietary fats and oils and a net importer of industrial fats and oils. These are the relations as they actually exist, not as they necessarily must be or must continue to be.

COLONIAL SOURCES OF FATS AND OILS

To a large extent the oilseeds and nuts of commerce move to countries situated in the temperate zones from colonies and dependencies in the tropics. The colonies or dependencies of Great Britain, Holland, France, Belgium, and the United States are the largest sources of supply of tropical oilseeds.

During the early years of this century Great Britain had by far the largest trade of any European country in foreign oilseeds and nuts, and was the principal user of imported vegetable oil materials. As the years passed, however, Germany became a keener and stronger competitor in both the producing and the distributing branches of the trade. Her colonization activities are well known. In several of the colonies fatty vegetable materials were the principal or among the principal articles produced, and great efforts were made to stimulate their production. In addition, steamship companies were subsidized in the colonial trade and German ports were encouraged to organize for the handling of oleaginous materials so as to compete with such well-established trading centers as Marseilles and Hull. Consequently, by 1913, German imports closely approached those of Great Britain; indeed, the British trade was becoming seriously exercised over loss of business. France also had a large trade in vegetable nuts and oils before the war, but it did not reach the proportions of the British or the German. Because of her large domestic supply of olives, she was not dependent on foreign sources to the same degree.

Shortly before the war, Germany far outstripped either Great Britain or France in her use of coconut and palm kernel oil. These, aside from linseed, were the principal vegetable fats imported. Great Britain, on the other hand, used a great deal of cottonseed, while France relied principally upon peanuts. Great Britain was the only one of the three that imported any appreciable amount of these

fats in condition suitable for consumption. She imported considerable margarin and lard compound from the continent.

The war stimulated imports of oilseeds into the allied countries, to furnish vegetable fats in replacement of animal fats of which domestic supplies were greatly reduced. On the other hand, Germany was unable to continue these importations during the war. After the war, the trade of the allied countries continued in large volume, and in recent years annual imports (both gross and net) of vegetable oils and oilseeds in terms of oil have usually somewhat exceeded the pre-war figures. This is clearly true of Great Britain and France, and probably of most other countries of western Europe. The German trade revived in spite of the loss of the German colonies. Because of adverse economic and financial conditions, however, the volume of imports into Germany remained for some years well below pre-war levels, and only with 1925 and 1926 have German imports reached 1913 levels.

During these recent years cottonseed oil has been in general use in the United Kingdom only, and this not from American but from Egyptian or Indian seed. France and Germany use very little. Coconut oil, on the other hand, is in general use in all countries. Cottonseed and palm kernel oil are more important in the United Kingdom (as well as linseed), and peanut oil is considerably more important in France; but in Germany, coconut oil is the principal vegetable oil used. The British, through their control of West African territories producing most of the palm oil and palm kernels of the world, naturally draw heavily upon these, although Germany is also a large taker of palm kernel oil and the United States of palm oil. France is unique in regard to the use of peanut oil, because of her control of Senegal, one of the principal sources of supply. Germany uses more soy bean, rapeseed, and sesame oil than Great Britain or France, a fact

that is rather remarkable in view of British connections in the Indian trade. All three countries use large quantities of linseed oil although not so much as America.

No quantitative information is readily available as to the proportions of the various oils that go into the different uses. The physical and chemical characteristics of the oils determine their use in main part, but since considerable substitution can be made the usage differs somewhat from country to country according to the availability of the various oils. In France, for instance, peanut oil is doubtless more generally used for margarin and salad oils than elsewhere. Similarly in Great Britain palm kernel oil serves many of the purposes to which coconut oil is put in America and Germany. The availability of palm oil for soap manufacture in Great Britain doubtless permits a larger use of animal fats and coconut oil for edible purpose there than in this country. Per capita consumption of margarin is considerably smaller in Great Britain than in Germany and the Scandinavian countries, but her total takings of vegetable fats and oils are larger than those of any other European country, apparently indicating very large industrial usage of inedible products. Careful investigation would show differing practices from country to country, manufacturing technique having been adapted to the supply of raw materials.

In the United States the use of imported oils is quite different because of the large domestic production of cottonseed oil; and the small per capita consumption of margarin and the large consumption of lard compounds also contribute to give American usage its peculiar cast.

COMPETITION OF DOMESTIC AND IMPORTED SUPPLIES

Every country with colonies or dependencies has more or less effective incentives, political and commercial, for increasing the trade of these colonies or dependencies with the mother country and with other countries. The mother countries accept oilseeds in return for services,

interest charges, and manufactures. In such countries the colonial vegetable oils are substitutable to some extent for native animal and vegetable fats and oils. The animal husbandries of the United States, Great Britain, Holland, Belgium, and France must market their fats and oils in direct competition with certain vegetable oils obtained from the colonies. The price reactions are sometimes direct, sometimes indirect. The circuitous nature of some of these relations is well illustrated in the case of Denmark. Denmark imports oilseeds, expresses the vegetable oil, feeds the cake as protein concentrate to dairy cows, churns the butter from the milk and ships it largely into export trade, uses the buttermilk as a basis for a hog industry of which the bacon passes largely into export, and of the expressed vegetable oil makes butter substitutes (plus some imported margarin) to be used in the domestic market to replace the butter and bacon exported. The net result is a profit which forms a material proportion of the national income.

North of the latitude of the Alps lard is preferred in cooking; southward, vegetable oils are preferred. Germany and the other countries of northwestern Europe (except Denmark, a net exporter, because of the peculiar development of her agriculture) import hog fat from the two exporting areas. The lower Danubian area (a net fat and oil exporter) exports hog fat because it produces fat in excess of its customary dietary needs. The United States (a net fat and oil importer) exports lard because a large fraction, possibly a majority, of our people prefer vegetable lard substitutes. Hog producers in northern Europe endeavor by tariffs to make defense against imported lard. What would happen directly to the hog raisers of northern Europe, and indirectly to those of the United States, if it should come to pass that lard substitutes should supplant lard in Europe, as has been the case in the United States, is an interesting subject for speculation.

Not merely do the hog producers of northern Europe strive for tariff protection against imported lard, but the dairymen agitate for tariff protection against imported vegetable oils because these are the principal raw materials for the enormous butter-substitute industry of western Europe. Similarly, there is agitation in Mediterranean countries for tariff protection against imported oils even though these countries are heavy exporters of olive oil, because the import of other edible vegetable oils reduces the domestic price of olive oil. In character and degree this demand for protection differs in no essential way from that in other agricultural produce or in manufactures. If all the countries from which vegetable oils are derived were independent, rather than colonial and dependent, their oil seeds would obtain entrance to the importing countries less readily than they do now.

Another aspect of this competition deserves consideration in its bearing on agricultural profits and tariff policies. The prime products of animal husbandry are milk and meat; the carcass fats, as we have seen, are secondary products. Cheap imported vegetable oils, largely from the tropics, are substitutable with indigenous fats and oils over a wide variety of uses and thus make for lower prices of the indigenous fats and oils. The lower the price level of the fats, the greater the load to be carried by the meats or by non-fat by-products. Since the prices of meats are relatively high and advances are met by restriction of consumption, and since rising hide and by-product prices arouse competition of substitutes, low prices for fat obtained by packers and merchants tend to be reflected back to agriculturists in the form of lower prices for live animals. So far as fat is concerned, the effect is greatest in the case of hogs, since the lard and the cured fat parts of the average hog exceed one-fifth of the live weight; in the case of the average steer, the net yield of commercial fat is relatively small, consequently the effect of low prices of

fats on the price of the live animal is smaller. Competition of artificial leather, bone substitutes, and other substitutes for animal by-products operates in the same way. In some measure these influences affect the remunerativeness of the entire system of diversified agriculture. Tariffs on importations of fats and oils, in so far as they might tend to raise the general price level of fats, would thereby tend to raise the return on the carcass fat produced in animal husbandry, to raise slightly in consequence the prices of live animals, and to improve slightly the profitableness of diversified agriculture.

The problem of tariff policy is especially complicated in the United States because the United States, unlike Europe, is a heavy producer of an important animal fat, lard, and an important vegetable oil, cottonseed oil, and because it draws most of its coconut oil from a dependency, the Philippines. Indeed, the United States is the only modern industrial state with as low a net import of fats and oils. No other industrial state has an export of animal fats to match the lard exports of the United States. No other modern state, except Mediterranean countries producing olive oil, has any considerable production of oil to match the cottonseed oil of the United States.

With the exception of olive oil the major fats produced in western Europe are the product of animal husbandry; and production by no means suffices to meet requirements. Indeed, much of the animal fat production, including milk fat, is dependent upon the importation of oil seeds. The oil cake remaining after the expression of the oil is fed to cattle and hogs, thereby helping to produce fat. The manure resulting from this feeding adds to the fertility of the soil. Thus the importation of oilseeds has three effects of the greatest value to the importing country. First, it contributes dietary and industrial fats directly. Secondly, it contributes concentrated animal feed by means of which meat and animal fats are produced.

Thirdly and lastly, the feeding of the oil cakes produces very rich manure, with which heavier crops of grains, roots, and legumes are raised than would be possible otherwise.

The vital importance of the importation of oilseeds into western Europe was brought out during the Great War. When the allies stopped the importation of oilseeds and of oil cakes into the Central Empires, importation of these commodities into Scandinavian countries and into Holland increased by an amount not very far from the average pre-war importation into Germany. These countries became practically feeding yards for Germany. When the importation of oilseeds and oil cake into neutral neighboring countries was brought under control by the allies, Germany began to feel a shortage of fat. This shortage was greater than was represented by her pre-war normal importation of fat, for inability to secure oilseeds and oil cake contributed to the deficiency of feeding stuffs. This necessitated a reduction of the cattle and hog population with a consequent reduction of the meat and animal-fat production. Because of the lack of such concentrated feeds as oil cakes the fat production—and especially the butterfat production—by the surviving animals fell below normal. And this was not all. The lack of concentrated feeding stuffs reduced the volume and the fertilizing value of manure, which in turn resulted in smaller yields of cereals, legumes, roots, and other crops.

It is obvious, then, that the oilseed trade is of vital importance to western Europe. It is not to be ignored by these nations in shaping their respective national agricultural policies.

VII

CONCLUDING OBSERVATIONS

In preceding sections there has been sketched in broad outline and in contrasting colors the background against which the individual fats and oils must be viewed if their behavior as commodities fitting into the general economic scheme of the world is to be understood. The presentation is a failure if it has not made clear that there has been little systematic study of the subject, that it presents matter of great interest to students of economic theory, that there are wide gaps in basic information, and finally that there are many problems important to American national welfare. Let us return for a moment to consideration of some of them.

In the first place we need to know more than we do concerning the effects of the importation of vegetable oils upon our own producers of fat and especially upon the producers of lard and of butterfat. We need to know the effect, prospective as well as present, upon the mixed farming which is so important to our general national well-being. Because until recently we have been net exporters of fats and oils and because we are still heavy exporters of lard, we have paid little attention to these questions. Since the war the situation has been changing and it is now high time that it be analyzed objectively and taken into consideration in shaping national policy with reference to agriculture.

However, to appraise the situation touched upon in the preceding paragraph we need to know vastly more than we do concerning tropical and other fats that are offered for import into the United States—the coconut, peanut, palm, palm kernel, soy bean, and other oils. We need to

tacked with hope of success in any other way. No other agencies have the resources or the power to gather the necessary basic statistical data. Only when these have been collected, tabulated, and made generally available can other agencies undertake the study of many of the economic aspects of the fats and oils situation. In the meanwhile it seems possible to mark off from these broader fields of investigation many specific smaller territories in which even now research may profitably be undertaken by agencies with lesser resources and less power than governments but with greater freedom of action and of opinion. It is toward the study and solution of problems of this sort concerned with the rôle of fats and oils in the world's economic situation that the Food Research Institute hopes from time to time to make some contributions.

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