ANIMAL FATS AND OILS

LOUIS E. ANDES

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ANIMAL FATS AND OILS

THEIR PRACTICAL PRODUCTION, PURIFICATION AND USES FOR A GREAT VARIETY OF PURPOSES THEIR PROPERTIES, FALSIFICATION AND EXAMINATION

A HANDBOOK

FOR
MANUFACTURERS OF OIL- AND FAT-PRODUCTS, SOAP
AND CANDLE MAKERS, AGRICULTURISTS,
TANNERS, Etc., Etc.

BY
LOUIS EDGAR ANDÉS

WITH 62 ILLUSTRATIONS

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PREFACE.

As in the case of Vegetable Fats and Oils, considerable improvements have been introduced into the preparation of the animal products belonging to the same category; and, whilst for the most part relating to mechanical methods, have given this industry a marked impetus.

Now-a-days the preparation of tallow and hog fat is conducted in a rational manner, and the manufacture of that valuable food-stuff—butter—is carried on according to methods calculated to thoroughly utilise the raw material—milk—and to yield a product endowed with a better flavour than under the primitive conditions formerly prevailing. Improvements have also been made in the preparation of bone fat, waste fat, fish oils, etc., all of which I have thought it advisable to include in the present work in order to render it more acceptable to those interested in the fat industry.

LOUIS EDGAR ANDÉS.

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ANIMAL FATS AND OILS.

INTRODUCTION.

The products known under the name of "animal fats" are closely related, in respect of both chemical and physical properties, to the vegetable fats. Like these latter, they are, almost exclusively, compounds of one, or frequently several, fatty acids with glycerine ethers; are, at ordinary temperatures, either solid, semi-fluid or perfectly liquid; leave behind permanent fatty marks on paper; dissolve in boiling alcohol and other liquids; can be mixed together when in a melted condition, *i.e.*, in the warm, and are all lighter than water, so that they float in that liquid. When rubbed in thin layers on other substances, such, for example, as the skin, wood, etc., they repel watery liquids, and thereby afford a certain amount of protection against the penetration of same. Finally, they exhibit what is generally denoted a "greasy feel" when handled.

The fats are encountered throughout the animal kingdom, in all its classes and subdivisions. They are met with both in mammals, birds, amphibia, fishes, and even in insects, and occur particularly in separate layers under the skin, interspersed in the flesh, between the intestines, or stored in the brain; and a great part of the nutriment absorbed into the animal economy is converted into fat. Under certain circumstances the fat accumulated in the animal body will serve to support the individual, for a short time, as a means for the continuance of life during periods when the supply of nutriment is either reduced or entirely suspended. This is observed in the case of animals (*e.g.*, bats, bears, hedgehogs, etc.) that lie dormant through the winter (hibernate) and awake in spring (or in a favourable season) reduced in flesh.

The amount of fat stored up in the animal body is a particularly variable quantity and depends on the supply of food, mode of life and other circumstances. As a rule, the accumulation of fat is favoured by a secure and undisturbed existence, but may also be considerably increased by artificial means, as we shall see later on. The different animals turned to account for their fat are comparatively few in number, and comprise in fact only those that are bred on a large scale to be utilised partly for food and partly for technical purposes. Moreover, the fat of many animals is uneatable, being of unpleasant odour and flavour; and in the case of many others it is not present in sufficient quantity to serve our purpose.

There can be no doubt that the fat of animals, equally with their flesh, was employed by man, even in the earliest times, for manifold purposes, originally, however, for food alone. The use of fat for curative purposes—value in which respect is still attributed to bear's grease, badger fat and dog's fat by country folk—came later. Burning fats for the purpose of illumination, their use for application to the body to enable it to better withstand inclement weather, as also for impregnating clothing and other articles in order to make them soft, supple and waterproof probably formed the next stage of extension; and, finally, in recent times only, their technical utilisation was developed.

As regards curative powers, the only fat at present playing an important part in this respect is cod-liver oil—scarcely any one now-a-days believes that bear's grease and other fats have any healing powers, and the substance sold under this name is merely lard and tallow.

As progress developed in chemico-technical matters, and as the population increased, attention was naturally directed towards the recovery and utilisation of fats, and we can see by the enormous consumption of soap, candles, etc., the great importance attaching to the production of animal fats in the present age. Moreover, the bye-products obtained in the working up of fat play an important *rôle*, and this is particularly the case with glycerine, which is now produced in enormous quantities. Whereas half a century ago the glycerine formed during saponification and left behind in the sub-lye was simply allowed to run to waste along with the lye, it is to-day a highly important article of commerce, the amount annually produced throughout the globe being some 40,000 tons—not altogether, it is true, from animal fat, but from vegetable fats as well. Of this quantity about 26,000 tons are produced in the manufacture of stearine and 14,000 tons in soap-making.

The preparation of fish oils—the best qualities of which are used as cod-liver oil for medicinal purposes, whilst the inferior grades are only used for technical purposes, serving as emollients in leather dressing—has also greatly increased in extent, although the industry has not, of course, assumed the same importance as that of the other animal fats.

So far as the method of preparing animal fats is concerned, this was until comparatively recently of a very primitive description: the crude fat was melted or "rendered" in open pans heated by direct fire either with or without water, perhaps then melted again for purification, and afterwards put on the market. The unpleasant exhalations attendant on some fat-rendering operations, especially when old fats (partly intermixed with putrescent flesh), bones, etc., were being treated, and which contaminated the atmosphere of all the neighbourhood round such tallow-boiling establishments, finally led the authorities to insist on a modification of the arrangements, so that at the present time fat-melting works with their perfected appliances carry on their occupation without producing any smell and without inconvenience to the vicinity. In recovering fat from bones, glue as well as fat is produced, the raw material being thereby fully utilised in a rational manner.

The importance attained by animal fats in the world's commerce can be gathered from the subjoined statistics, though the figures will certainly have already been exceeded since the dates mentioned.

Fish oil annually produced.—*Spermaceti* and *Sperm Oil*, 1,485,000 hectolitres (of 22 gallons); other kinds, 1,170,000 hl. Oil from sea fowl, 58,500 hl.

The amounts of train and fish oils imported into England were :—

	1888.	1889.	1890.
Tons - - - - -	16,861	21,051	20,302
Value - - - - -	£323,579	£442,699	£419,926

Exports from the United States :—

	1889.	1890.
Gallons - - - - - - -	483,208	1,844,041
Value - - - - - - - -	$127,412	$440,773

German imports and exports :—

	1890.	1891.
Imports - - - - - - - -	142,668	124,008
Exports - - - - - - - -	1,948	1,871

Liver Oil.—Newfoundland produces annually 1,250,000 galls., valued at £200,000; Norway exported (in 1877) 130,600 barrels, of a value of £336,600; Norway and Sweden in 1879, 143,165 hl. (about 3,150,000 galls.).

Spermaceti and Sperm Oil.—America produced in 1878 1,300,959 galls.; 1879, 1,285,454 galls. The exports of sperm oil from New York amounted to 912,603 galls. in 1878 and 1,089,137 galls. in 1879. This trade has somewhat fallen off in recent years; in 1889 the exports amounted to 98,823 galls., worth $69,628, and in 1890 162,565 galls., value $124,601.

Solid Spermaceti exported from the U.S.A.:—

	1888.	1890.
Lbs. - - - - - - - - -	425,479	447,384
Value - - - - - - - -	$11,386	$116,757 (?)

Lard and Lard Oil.—The United States produced:—

	1884-85.	1885-86.	1886-87.
Lbs. - - - -	480,405,000	514,230,000	527,032,000
	1887-88.	1888-89.	1889-90.
Lbs. - - - -	487,179,000	483,902,000	624,227,004

One-third to one-half the above is "compound lard" (lard mixed with cotton-seed oil and beef stearine). The production of this "compound lard" rose to 300,000,000 lbs., but receded in 1890 to 225,000,000 lbs.

Lard exported from the U.S.A.:—

	1886.	1887.	1888.	1889.	1890.
Lbs. -	231,509,570	321,523,746(?)	270,245,146	318,242,990	471,083,598
Value -	$22,523,197	$22,703,921	$23,516,097	$27,329,173	$33,455,520

One-third of the exports come to Great Britain and Ireland.

German imports and exports of *Lard*:—

	1890.	1891.
Imports - - - - - - - -	910,277	875,343
Exports - - - - - - - -	1,364	1,484

Tallow.—Total production in Europe (1882), 355,700 tons; U.S.A., 330,000 tons; other countries, 60,000 tons; total—745,700 tons. The exports of Russian tallow have considerably diminished of late years; in 1860 they totalled 40,300 tons; 1870, 21,100 tons; 1880, 10,400 tons. On the other hand, the exports from the U.S.A., Australia and, in a smaller degree, from South America have increased. In 1883 the exports were: U.S.A., 45,000; Australia, 28,000; Argentina, 10,500; Uruguay, 12,000 tons.

Exports from the U.S.A. :—

	1886.	1887.	1888.	1889.	1890.
Lbs. -	52,699,115	84,099,951	75,470,826	77,844,555	112,745,370
Value -	$2,435,349	$3,772,837	$3,736,488	$3,942,024	$5,242,158

German imports and exports in metercentners (of 2 cwt.) :—

	1888.	1889.	1890.	1891.
Imports - - -	62,263	118,126	132,232	108,133
Exports - - -	12,047	5,154	5,925	6,812

OCCURRENCE, ORIGIN, PROPERTIES AND CHEMICAL CONSTITUTION OF ANIMAL FATS.

Fat is found in all the organs constituting the animal organism—and in individual places accumulated in large quantity—as well as in all animal fluids, with the exception of urine. Certain animals exhibit a greater tendency to secrete fat than others, the domestic animals having this faculty particularly well developed. In the animal organism fat is generally found enclosed in special cells, in larger amount in connective tissue, in the *panniculus adiposus* under the skin, in the plexus of the abdominal cavity, in the vicinity of the kidneys, in the marrow of the bones and spine, in the brain, in the liver and in the milk; occurring pathologically in so-called fatty tumours and in fatty degeneration of the various tissues.

Concerning the origin of the fat in the animal body the following may be asserted: The fat stored up in the bodies of animals fed on a generous diet does not consist solely of ready-formed fat absorbed from the food, but is to a considerable extent elaborated in the body from other chemical compounds. From an exhaustive study of the composition of the nutriment of the herbivorous animals, coupled with a knowledge of the remarkable changes undergone by organic bodies outside the organism and reflection on the importance of the individual constituents of nutrition, Liebig was led to believe that the carbohydrates (starch, dextrin, sugar) played an important part in the formation of fat within the body; and on the basis of his assumptions the opinion prevailed during several decades that the formation of fat from carbohydrates was an unassailable fact. In proof hereof were specially advanced the facts that in the carnivora which, apart from fat, consume no non-nitrogenous food, the elaboration of fat is generally deficient but increases considerably when they are placed on a mixed diet with an excess of carbohydrates; that the bulk of the food of herbivorous animals consists of carbohydrates; and finally, that bees when fed for a long time solely on wax-free honey or sugar are still able to produce wax—*i.e.*, a fatty body—without loss of health or weight.

Recent researches made by Voigt and Pettenkofer, however, have made it seem very probable that the albuminoid substances in the food are, apart from the ready-formed fats therein, the chief source of fat, and that quite a different interpretation must be put on the indubitable functions discharged by the carbohydrates in this connection; the latter do not represent the special material from which the fat stored in the body is produced direct, but are none the less essential, in the dietary of the herbivorous animals at least, in order that fat may be elaborated.

Pettenkofer and Voigt have demonstrated that in both carnivorous and herbivorous animals the decomposition of albuminoid substances invariably results in the separation of fat which in the course of further substantive alterations is either completely consumed, or else, when protected from further oxidation by the presence of other easily oxidisable substances like the carbohydrates, remains as a residue in the body and is laid up therein as a valuable store of reserve force to be drawn upon in time of need. The importance of the carbohydrates in the formation of fat is therefore restricted to preventing the combustion of the fat separated in the decomposition of the albuminoids, so that the fat has the opportunity of accumulating within the tissues. Actually, the fat and albuminoid matters of the dietary are always sufficient, even in the case of the enormous fat production exhibited by milch kine, to yield the fat formed, and fattening with carbohydrates is only efficient provided albuminoids be simultaneously supplied.

By means of a methodic system of dieting ("fattening" or "feeding") an increase of the fat and flesh of animals destined for the slaughter-house can be produced. As the body fills up in the course of fattening the animal assumes a condition of imperfect health, for which reason highly justifiable objections have been raised against over fattening (a course of feeding first practised in England) not only from a medical standpoint but also in view of the utilisation of the meat. The most nutritious and best flavoured meat is only obtainable from animals in a condition ranging from incipient fattening up to the half-fat stage, whilst very fat beasts, on the other hand, yield chiefly tallow and fat, but their flesh and blood are deficient in the constituents acting most effectually on the transfer of matter in the animal economy.

The following animals are those whose fat is most prized and utilised: Oxen, sheep, pigs and horses; among birds the goose almost exclusively; and also the large marine mammals, such as the whale and seal, the dolphin, merlangus, shark, and a number of smaller fishes, such as the cod, ray, herring, sprat, sardine, anchovy, etc.

The storage places of fat in the animal body are various. It is often encountered in considerable masses directly under the skin (as in the pig) or between the intestines (belly fat), in the brain (in the sperm whale), in the liver (of numerous fishes); or, finally, distributed throughout the whole body, so that in order to recover it the entire carcase must be boiled or pressed (small fish, such as the anchovy, etc.).

At ordinary temperatures the animal fats when in a pure state are solid or liquid; the colour ranges from white to yellowish-white, pale yellow or brown (fish oils). The solid fats melt at between 20° and 45° C., and the liquid fats become semi-fluid or quite firm at temperatures from 5° C. downwards. The boiling-points are various, and when heated still further all the fats are decomposed, their glycerine being converted into acrolein, a substance with a most unpleasant smell. The specific gravity of the animal fats is lower than that of water and can, as in the case of the vegetable fats, be regarded as a characteristic indication of their purity.

When fresh, the animal fats, for the most part, have an agreeable odour, the only exceptions being sundry fish oils; on the other hand, when old, they have generally a rancid and unpleasant, sometimes putrescent and even repulsive, smell (old bone fat, blubber, etc.). The flavour of some, *i.e.*, those generally employed for alimental purposes (butter, goose fat, lard), is agreeable; in others (tallow, especially mutton tallow), unpleasant; and in the case of fish oils, occasionally nauseous. Nearly all fats will produce, even at the ordinary temperature, grease spots which do not disappear on warming, and even those of highest melting-point give rise to grease spots when heated. When absorbed by a wick, all fats will burn with a more or less illuminating, smoky and strong-smelling flame.

The solid fats when viewed under the microscope at the ordinary temperature appear throughout as a mixture of solid and liquid substances. The solid portion consists mainly of crystals in the shape of plates, needles or tufts, which are composed of free fatty acids. If the fat be warmed on a glass slip up to the melting-point, sundry solid amorphous granules will still generally be left behind in the mass.

On cooling, the fatty acids crystallise out again, mostly in the form of needles. In fats poor in olein the liquid portion appears in the form of drops, but forms the fluid matrix in those rich in olein. This fluid mass when viewed under the microscope frequently appears not to be homogeneous, but to contain drops with a different power of refraction from the rest.

The fats are insoluble (or, according to recent statements, soluble, though with extreme difficulty) in water, and but little soluble in cold alcohol, though generally soluble in hot alcohol, ether, benzene, petroleum ether, etc. (at least in the warm).

Like their vegetable congeners, the animal fats consist principally of neutral glycerides of the fatty acids, and therefore have the general formula $C_3 H_5 (O OC R^1)$, wherein R^1 represents a monovalent hydrocarbon radicle. In addition to this the fats may also contain free fatty acids. Sperm oil and the spermaceti obtained therefrom contain, however, no glycerides, but ethers of the higher alcohols of the fatty series, and should (along with shark oil and probably all the oils derived from marine animals and having a sp. gr. of less than 0·888 at 15° C.) properly be relegated to the category of the waxes. All fats may be saponified, *i.e.*, decomposed into fatty acids and glycerine, by alkalis, dilute acids and by means of superheated steam. By this process the following acids and alcohols have been separated from the fats and waxes :—

A. ACIDS.

1. *Saturated Acids of the General Formula* $C_n H_{2n} O_2$.

$C_4 H_8 O_2$ Butyric acid.
$C_5 H_{10} O_2$ Isovaleric acid.
$C_6 H_{12} O_2$ Caproic acid.

$C_8 H_{16} O_2$ Caprylic acid.
$C_9 H_{10} O_2$ Pelargic acid.
$C_{10} H_{20} O_2$ Capric acid.
$C_{12} H_{24} O_2$ Lauric acid.
$C_{14} H_{28} O_2$ Myristic acid.
$C_{15} H_{30} O_2$ Isocetic acid.
$C_{16} H_{32} O_2$ Palmitic acid.
$C_{17} H_{34} O_2$ Daturic (margaric) acid.
$C_{18} H_{36} O_2$ Stearic acid.
$C_{20} H_{40} O_2$ Arachic acid.
$C_{21} H_{42} O_2$ Medullic acid.
$C_{22} H_{44} O_2$ Behenic acid.
$C_{24} H_{48} O_2$ Lignoceric (carnaubic) acid.
$C_{25} H_{50} O_2$ Hyenic acid.
$C_{27} H_{54} O_2$ Cerotic acid.
$C_{30} H_{60} O_2$ Melissic acid.
$C_{64} H_{128} O_2$ Theobromic acid.

2. *Unsaturated Acids (with Double Bond) of the General Formula* $C_n H_{2n-2} O_2$:—

$C_5 H_8 O_2$ Tiglic acid.
$C_{16} H_{30} O_2$ Hypogeic acid.
$C_{18} H_{34} O_2$ Physetoleic acid.
$C_{19} H_{36} O_2$ Oleic acid.
$C_{22} H_{42} O_2$ Doeglic acid.

3. *Acids (with Triple Bond) of the General Formula* $C_n H_{2n-4} O_2$:—

$C_{16} H_{28} O_2$ Linolic acid.
$C_{17} H_{30} O_2$ Elæomargaric acid.

4. *Acids of the General Formula* $C_n H_{2n-6} O_2$:—

$C_{18} H_{30} O_2$ Linolenic acid.
$C_{18} H_{30} O_2$ Isolinolenic acid.

5. *Ketone Acids of the General Formula* $C_n H_{2n-2} O_3$:—

$C_{18} H_{34} O_3$ Ricinoleic acid.
$C_{18} H_{34} O_3$ Rapic acid.

B. Alcohols.

1. *Trivalent Alcohol of the Formula* $C_n H_{2n+2} O_3$:—

$C_3 H_8 O_3$ Glycerol (glycerine).

2. *Monovalent Alcohols of the Fatty Series, with the Formula* $C_n H_{2n+2} O$:—

$C_{16} H_{34} O$ Cetyl alcohol (ethal).
$C_{18} H_{38} O$ Octodecyl alcohol.
$C_{27} H_{56} O$ Ceryl (iso-ceryl) alcohol.
$C_{30} H_{62} O$ Myricyl (melissyl) alcohol.

3. *Monovalent Aromatic Alcohols.*

$C_{24} H_{44} O$ Cholesterin.
$C_{26} H_{44} O$ Isocholesterin.
$C_{26} H_{44} O$ Phytosterin.

The fats consist most frequently of the glyceride of palmitic acid (palmitin, tri-palmitin) $C_3H_5 (C_{15}H_{31}CO_2)_3$; the glyceride of stearic acid (stearine, tri-stearine) $C_3H_5 (C_{17}H_{35}CO_2)_3$; the glyceride of oleic acid (olein, tri-olein) $C_3 H_5 (C_{17} H_{33} CO_2)_3$. Other acids occur in small quantities in various fats, a high proportion of such an acid being generally characteristic of a certain fat. Such are:—

Butyric acid, as a glyceride (butyrin) in the proportion of 2 per cent. in cow's butter.

Isovaleric acid, occurring in combination with glycerine in dolphin and porpoise oils.

Of the *caproic acids*, isobutylacetic acid occurs as caproin in butter, in which caprylic and capric acids also are present in the form of caprylin and caprin; so that cow's butter contains about 8 per cent. of the glycerides of these acids.

Medullic acid, as a glyceride in ox marrow.

Hyenic acid, in the anal gland of *Hyæna striata*.

Physetoleic acid, in sperm oil; and

Doeglic acid, in Arctic sperm oil.

The solid and liquid animal fats differ from one another in consistency, this being dependent on the varying proportions of the individual glycerides present in each; stearine and palmitin being solid at the ordinary temperature, whereas olein is then liquid. The foregoing constitute the basis of the fats and may be considered as a tri-glyceride. All rancid fats contain free fatty acids, the formation of which rests on a decomposition effected by the air, whereby glycerine and free fatty acids are produced.

The saturated fatty acids up to capric acid, and the oleic, doeglic and various vegetable fatty acids are liquid at the ordinary temperature, the remainder being solid. Butyric, caproic, caprylic and capric acids, being capable of distillation without decomposition, under ordinary pressure, are therefore styled *volatile fatty acids.*

1. *Butyric Acid.*

This acid is liquid at the ordinary temperature and exhibits, when freshly distilled, an odour resembling that of acetic acid, but in a dilute condition has a very strong smell like rancid butter. It boils at 162·3° C., sets in a flaky condition at – 19° C., and has a sp. gr. of 0·958 at 14° C. It is readily soluble in water and can be separated therefrom as oily drops by calcium chloride or by common salt; with alcohol and ether it is miscible in all proportions.

Solutions of butyric acid have a corrosive acid taste, redden litmus and decolorise a slightly alkaline phenolphthalein solution. Methyl orange also is reddened by solutions of butyric acid containing no butyric salts. If a dilute aqueous solution of this acid be distilled the acid passes over completely in the distillate; in the case of very dilute solutions the attainment of this object is facilitated by previously neutralising the acid with soda, concentrating the liquid by evaporation, and distilling after adding dilute sulphuric acid.

Concentrated butyric acid when warmed with alcohol and concentrated sulphuric acid forms butyric-ethyl-ester (ethyl butyrate), which is recognisable in small quantities by its very agreeable odour of pine-apple. To detect the presence of butyric acid in very dilute solutions by this reaction the liquid is neutralised with soda, evaporated to dryness, and the residue warmed with alcohol and sulphuric acid. A portion of the butyric acid is also etherised during the saponification of fats, containing this acid, by strong alcohol and caustic potash.

2. *Caproic Acid.*

Of the isomeric caproic acids isobutylic acid occurs in fats. It is a liquid, soluble in but not miscible with water, and possesses a smell resembling that of perspiration. The sp. gr. is 0·925 at 20° C.; boiling-point, 199·7° C.; setting-point, below − 18° C., at which temperature it is still liquid.

3. *Caprylic Acid*

is also liquid, but sets, on cooling down to 12° C., to a crystalline mass, melting at 16·5° C. Boiling-point, 236° to 237° C.; sp. gr. at 20° C., 0·914. It has an intense smell of perspiration and is soluble in 400 parts of water.

4. *Capric Acid*

forms at the ordinary temperature fine flakes which melt at 31·3-31·4° C. and emit a goaty odour. The sp. gr. of the melted acid is 0·93 at 37° C.; it boils at 268-270° C., and 1 part of the acid is soluble in 1000 parts of boiling water.

5. *Palmitic Acid.*

Pure palmitic acid consists of fine tufted groups of needles, or, after melting and re-solidification, of a crystalline scaly mass with a nacreous lustre; it is tasteless and inodorous, melts at 62° C., and at this temperature has in the liquid state a sp. gr. of 0·8527. At about 350° C. it is for the most part volatile without decomposition and will boil at 268·5° C. when the pressure is reduced to 100 mm. of mercury.

When melted palmitic acid is placed on paper, or an alcoholic or ethereal solution of the acid is left to evaporate thereon, a grease spot is produced. This acid is soluble with difficulty in cold alcohol, 100 parts of the solvent taking up only 9·32 parts of acid, but it is very readily dissolved by boiling alcohol, and may therefore be very easily re-crystallised from this solvent. The alcoholic solution has an acid reaction.

Dilute acids have no action on palmitic acid, but it dissolves in concentrated sulphuric acid, re-crystallising, however, unchanged on dilution. Boiling concentrated nitric acid attacks it very slowly. The salts of palmitic acid are very similar to those of stearic acid, but are somewhat more readily soluble.

6. *Stearic Acid.*

Pure stearic acid crystallised from alcoholic solution forms white lustrous laminæ which melt at 69·2° C. to a perfectly colourless fluid and set to a translucent crystalline mass on cooling. When heated to 360° C. it begins to boil and partly decomposes, but may be distilled without alteration under reduced pressure—at 291° C. under a pressure of 100 mm. When distilled by superheated steam it also passes over without apparent decomposition, but according to observations made in the distillation of fatty acids on a working scale a small portion is really decomposed, being converted into solid hydrocarbons of the $C_n H_{2n+2}$ series.

The sp. gr. of this acid at 11° C. is almost identical with that of water, but at higher temperatures it floats in the latter liquid owing to its greater coefficient of expansion. The sp. gr. of the acid melted at 69·2° C. is 0·8454.

Stearic acid is devoid of flavour or smell, handles greasy, and will leave a greasy mark on paper whether applied in the melted state or in solution. It is insoluble in water, but readily soluble in hot alcohol, though in cold alcohol it is even more difficult to dissolve than palmitic acid. One part of stearic acid dissolves in 40 parts of absolute alcohol; ether absorbs it readily, and at 23° C. 1 part of benzene will dissolve 0·22 part, and 1 part of carbon bisulphide 0·3 part of stearic acid.

7. *Hypogeic Acid.*

White needles, melting at 33° C., gradually turning brown and decomposing in the air, forming liquid fatty acids of rancid flavour.

8. *Physetoleic Acid*

has the same composition as the preceding acid, but differs considerably therefrom in being unaltered by the action of nitrous acid. It melts at 30° C.

9. *Oleic Acid.*

It is difficult to obtain oleic acid in a perfectly pure state. In this condition it appears as a colourless and inodorous oil which sets at 4° C. but does not melt again below 14° C.; the sp. gr. at this temperature is 0·898. Under ordinary pressure the acid is undistillable, but when heated by steam at a temperature of 250° C. passes over unchanged.

When perfectly pure it does not redden litmus paper, but, on the other hand, exerts an acid reaction on phenolphthalein, since the fresh fatty acid mixture (very rich in oleic acid) prepared from fats by saponification and subsequent acidification of the soap solution can be accurately titrated by means of this indicator.

When exposed to the air oleic acid becomes yellowish or yellow, smells very rancid, and reddens litmus.

This acid is insoluble in water, but readily soluble even in dilute cold alcohol. It may, however, be thrown down from its solutions by the addition of a large volume of water. An attempt has been made by David to found a method of separation for this acid on account of its greater solubility than the solid fatty acids in a mixture of alcohol, water and acetic acid.

If into 7 parts (1 molecule) of oleic acid there be dropped gradually 4 parts of bromine (1 mol.), with continual shaking, the whole of the bromine will be taken up and dibromostearic acid will be formed. From its method of preparation this body is known as the bibromide of oleic acid. The reaction occurs according to the equation :—

$$\underset{\text{(Oleic acid.)}}{C_{17}H_{33}COOH} + Br_2 = \underset{\text{(Dibromostearic acid.)}}{C_{17}H_{33}Br_2COOH.}$$

When suitably purified the product forms a clear oil. A similar reaction is obtained with an alcoholic solution of oleic acid in presence of an alcoholic solution of iodine containing mercuric chloride.

If nitrous acid be allowed to react on oleic acid the latter sets hard in a short time and becomes converted into the isomeric elaidic acid, which can then, by re-crystallisation from alcohol, be obtained in the form of plates melting at 45° C.

10. *Doeglic Acid,*

$C_{19}H_{36}O_2$, has received but little attention hitherto ; it is a yellow oil similar to oleic acid and setting at 4° C.

When fats or fatty acids are treated with caustic alkalis or lead oxide they are saponified. Concentrated alkaline lyes effect saponification with great difficulty, and therefore none but dilute lyes should be used. In the process of saponification stearine and palmitin are more quickly decomposed than olein.

On being melted with caustic potash, oleic acid = autopalmitic acid ; erucic acid = auto-arachic acid ; hypogeic acid = automyristic acid, and their isomers are decomposed into palmitic, arachic myristic and acetic acid. Concentrated sulphuric acid, in proportions of from 8 to 10 per cent., forms with fats at high temperatures sulpho acids, which, when treated with water, split up again into free fatty acids, glycerine and sulphuric acid. If fats or oils be treated with alkali carbonates, albumin, or an aqueous solution of gum arabic, they are thereby emulsified, and the same result is obtained by the action of ammonia. Alcoholic ammonia solution when allowed to act for a long time at ordinary temperature converts the fats into acid amides.

Chlorine and bromine form *substitution products* with the fats or fatty acids of the methane series. Iodine does not, but forms, however, like the above re-agents, *addition products* with the glycerides or the fatty acids of the unsaturated hydrocarbons.

Nitric acid exerts a strong oxidising reaction on the fats, etc., and forms oxalic acid, succinic acid and adipinic acid.

On exposure, especially in thin layers, to the air, the animal fats turn rancid ; they, however, never dry, as do certain of the vegetable oils, to a solid skin, but remain always in their original, more or less greasy, condition. In becoming rancid a part of the non-volatile fatty acids, especially oleic acid, is liberated, and occasionally a complete separation into fatty acids and glycerine occurs. Rancidity spreads in solid animal fats to a much smaller extent than in the vegetable oils, and they keep longer and better in proportion as their olein content is lower and that of the glycerides of the solid fatty acids higher. This condition (rancidity) is, however, in a high degree prejudicial to the animal fats on account of its effect on the flavour. Under defective storage conditions and under the influence of ordinary sunshine temperature, rancidity sets in so quickly that butter, for example, may become uneatable in a few days if not sufficiently protected from the air. The opinions prevalent on the causes of rancidity are somewhat divergent, but there can be no doubt that when air is sufficiently excluded rancidity, if not altogether prevented, can be retarded for a considerable time.

Liebig put forward the view that rancidity is induced by the influence of the extraneous substances present in the fat; Löhwig assumed a fermentative action in presence of water and air; whereas Kosch considered it due to oxidation by atmospheric oxygen, an opinion also shared by Duclaux; and Berthelot ascribes it more particularly to moisture, the action of which is facilitated by the presence of extraneous substances, oxidation being merely a concomitant reaction. Von Rechenberg, Flügge, Paschulin, H. Schulz and Neneki believe rancidity to be caused by the action of unorganised fat-destroying ferments, or by microbes. Gröger assumes that in turning rancid the fat is decomposed by water into fatty acids and glycerine, followed by oxidation through the action of atmospheric oxygen, both on the fatty acids and on the glycerine, since the latter is no longer detectable in a free state. The fatty acids are split up into bodies (acids), poor in carbon but rich in oxygen, belonging partly to the fatty acid series and partly to the oxalic acid series. Among the latter class azelaic acid ($C_9 H_{16} O_4$) has been identified.

Ritsert, who occupied himself very intently with the establishment of the causes of rancidity, demonstrated that the rancidity of pure fat is not caused by either aerobic or anaerobic bacteria. The fat when protected from air and light remained perfectly sweet, and germs inoculated therein died, although able to live in rancid fat. Neither can fermentative action be assumed, since sterile fat heated in a closed vessel for several hours at 140° C. becomes rancid under the influence of light and air. Moisture is non-essential to rancidity, dry fat becoming more rancid under the influence of air than when moist; but the process is one of oxidation solely, induced by atmospheric oxygen, without the collaboration of any organisms. The operation proceeds more rapidly in proportion as light is admitted, oxygen not being absorbed when light is excluded, neither does air cause rancidity in the absence of oxygen. Pure lard kept in the dark remains sweet even after a lapse of two months. The carbon dioxide of the air has the same influence on fat in the absence of light as pure carbonic acid, only less intense, and is absorbed by fat both in the light and in the dark in comparatively small amount, the fat becoming thereby tallowy, but not rancid. Both nitrogen and hydrogen are inactive towards fat, whether in the light or in the dark, and pure butter behaves exactly like pure lard.

Aerobic and anaerobic bacteria can live on rancid fat, but not if an excess of free fatty acids be present.

The practical results of these researches is that the *prime essential condition for the prevention of rancidity in fats is complete exclusion of air*, which being secured, exposure to the light or storage in the dark is immaterial.

PREPARATION OF ANIMAL FATS AND OILS.

The method employed for preparing animal fats and oils, that is to say, the treatment of the crude fats, differs somewhat from that pursued for the vegetable fats and oils, but finally conduces to the same end, *viz.*, separation from the accompanying extraneous substances—non-fats. In all materials yielding vegetable fats and oils we have to do with fruits, seeds, etc., forming a dry, solid, and occasionally even hard mass, from which the fats can be obtained solely by the application of considerable force, or, when in a pulverised or pulpy condition, by extraction with special solvents. The animal fats, on the other hand, are devoid of the characteristic shell encasing the vegetable materials, the fat lying distributed throughout various parts of the animal body and enclosed in, or completely occupying, cellular tissues; this mode of occurrence of the animal fats influences the method of treatment to be employed.

Whilst the oil- and fat-producing seeds and fruits will bear any length of transport, and come to us from distant parts of the world to be worked up, the crude animal fats must be treated within a short time and generally at the place of their production if they are to be prevented from becoming putrescent, whereby their quality as well as the amount of yield would be seriously depreciated. True, there are certain methods of transport that can be employed and, as in the case of meat brought from America and Australia, will preserve the raw material intact; only, these are much too expensive, and there is, moreover, no reason why the material should not be treated on the spot.

Most of the animal fats are prepared by a simple process of melting (rendering) in suitable pans, and when separated from the residual tissue by straining are ready for further use. Other fats, *e.g.*, blubber (fish fat), are partly expressed by the pressure of the material itself when piled up into large heaps, the remainder being recovered—as in some other instances—by boiling in water or by the action of the press. Butter is obtained by a process peculiar to itself, the finely divided fat globules in the milk uniting, under the influence of concussion and agitation, to finally form a lump of fat.

The extraction process which plays a great part now-a-days in the recovery of vegetable fats and oils, on account of the greater yield it ensures, is employed for animal fats in individual cases only, *e.g.*, the recovery of bone fat and of the residual tallow in greases.

In consequence of this peculiar composition of the raw material the mechanical appliances used in the preparation of the fats are different from those for vegetable fats and oils. They consist of:—

1. Machines for comminuting the fat;
2. Pans of various construction for melting down the crude fat;
3. Extraction plant for bone fat whereby glue can be recovered at the same time;
4. Presses for pressing blubber, as well as for separating the liquid and solid fats;
5. Filtering apparatus.

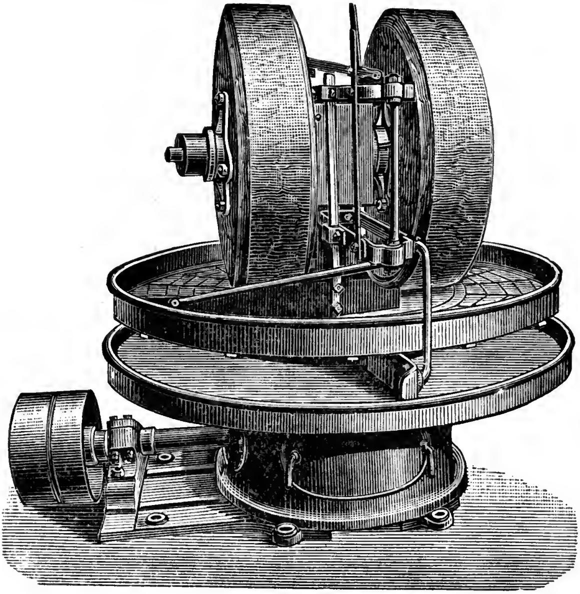

FIG. 1. Edge Runners for Crushing Fat.

Latterly also the operation of separating the fat of fishes and marine mammals into its solid and liquid components by centrifugal force has come into practice. The centrifugal machines used for this purpose deliver the liquid fat either over the edge or through lateral apertures in the inner drum; and machines of any known type are suitable.

Those varieties of tallow (raw tallow, core or kidney suet) that are used for making artificial butter are separated into their solid and liquid constituents by heavy pressure, and the so-called press tallow is prepared in the same manner by pressing tallow previously refined by melting.

The purification of the animal fats is effected by repeated meltings over water, or bleaching by chemicals—an operation but seldom resorted to. For the removal of small solid particles the fat is liquefied and poured through sieves or filter cloths. Blubber is also treated the same way or clarified by filtration by means of various mechanical appliances, such as filter presses or filtering apparatus of the kinds described in the author's work on *Vegetable Fats and Oils* (*q.v.*).

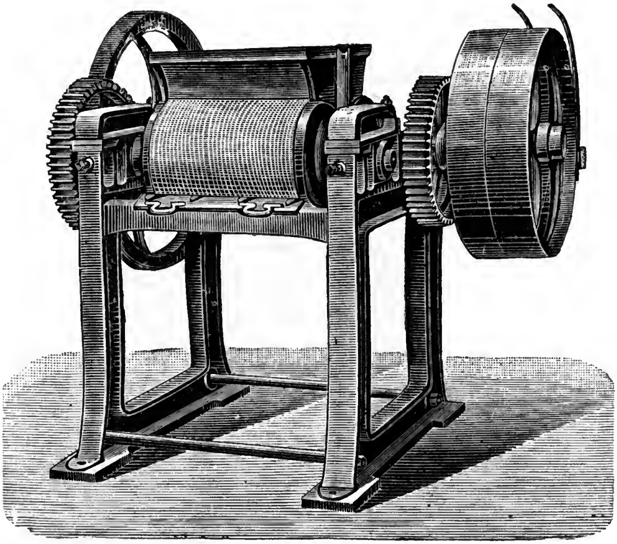

Fig. 2. Fat-Grinding Mill (W. Rivoir).

MACHINERY FOR BREAKING DOWN FAT.

Animal fats are delivered to the melter in lumps of all sizes, sometimes (as in the case of whale blubber) even in large blocks of considerable circumference and thickness;

but they cannot be worked up while in this condition since it would, on the one hand, necessitate the use of excessively large vessels, and on the other, the melting down in an unbroken state would take up too much time. However, it is not merely a question of dividing the fat into small portions, but also, and principally, of breaking down and loosening the cellular tissues in which the fat is enclosed, without which rupture of tissue an insufficient yield of pure fat would be obtained and the greater part of the material would have to be exposed to an excessively high temperature in order to make all the fat run out. The fat is therefore comminuted before melting, an operation that can be effected in divers ways. The simplest but most cumbrous and tedious method is by chopping on a block with a sharp knife or hatchet. A better plan is to employ a knife, movable vertically about a fixed point—a kind of chopping machine—but this also is insufficient for working on a large scale. In England edge runners, *i.e.*, heavy millstones made to revolve over a horizontal surface by means of a driving pulley (placed

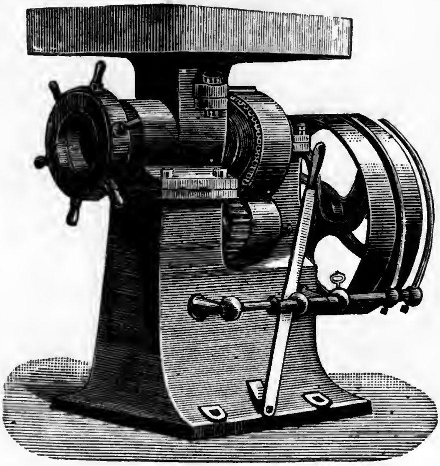

FIG. 3. Fat-Cutting Machine with Revolving Knives.

above or below), are used, and crush the fat by their weight, the membrane of the cellular tissue being thereby ruptured and the fat converted into a pulpy mass of a considerable degree of fineness.

Roller mills may also serve for crushing fat, but the fat-grinding machine shown in Fig. 2 is more efficient.

This machine consists of an iron frame on which are mounted grooved (sharp-edged) rollers driven by toothed gearing and belting pulleys, and at the top a wooden box or hopper feeding the fat to the rollers. When the rollers are set in motion and the fat placed in the box, the rollers (which move in opposite directions) draw the fat in, cut it and crush it, and then allow it to drop into a receiver situated underneath. In this case the material is not only torn apart but comminuted as well.

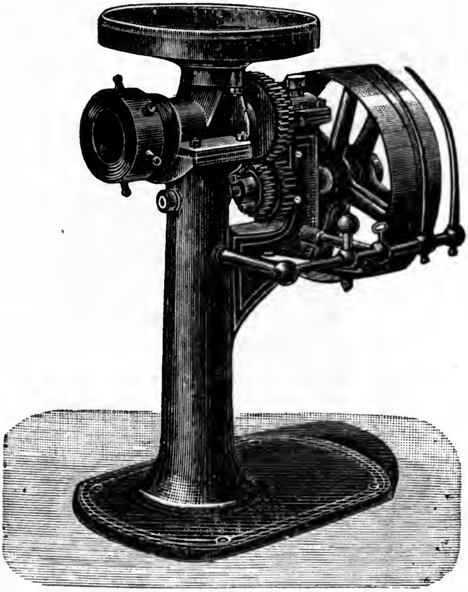

FIG. 4. Fat-Cutting Machine with Revolving Knives.

The most efficient of all are the cutting machines such as are shown in Figs. 3 and 4. In the hollow of the cast-iron stand a number of sharp-edged knives are placed, which revolve, and thereby rapidly cut in pieces the material placed in the upper dish, and deliver it by its own weight into a receiver below.

rendering

PANS AND APPARATUS FOR FAT MELTING.

The pans for melting the fat may be selected in accordance with the requirements of the business, so long as it is merely a question of small quantities or of such kinds of fat, *e.g.*, hog fat, as evolve no malodorous vapours, or, finally, when the works are situated in a place where the neighbourhood suffers no inconvenience by the production of a strong smell, *e.g.*, blubber-melting works in the vicinity of the fishery. The pans may be mounted either on portable stoves, as is particularly the case in blubber refining, or else surrounded by brickwork, and, therefore, fixtures. In either case, however, the heating gases should come in contact

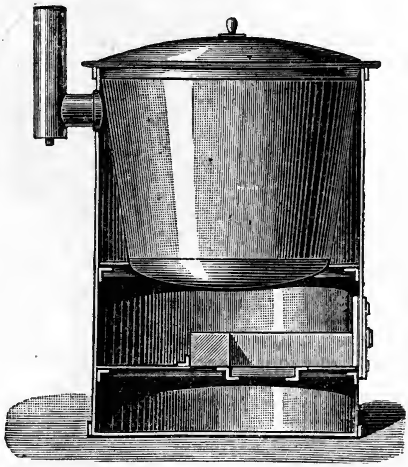

FIG. 5. Portable Melting Stove with Pan.

with the bottom of the pan only, in order to prevent the melted fat becoming overheated, a condition that would result not only in the discoloration (browning) of the fat, but also cause danger from fire. Iron or wooden vats heated by a steam coil, or jacketed pans, may also be advantageously employed.

A portable melting pan is depicted in Fig. 5, consisting of a sheet-iron stove with furnace door and flue and a wrought-iron or copper pan. The dome-shaped bottom of the pan is protected (around the spring of the dome) from the action of the fire by means of a partition wall.

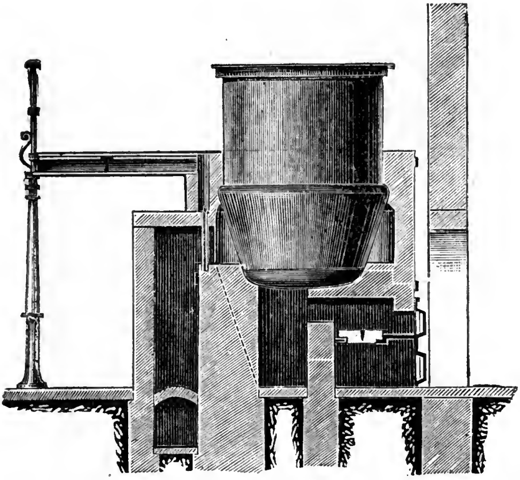

FIG. 6. Fixed Pan Heated by Direct Fire.

A fixed pan heated by direct fire is shown in Fig. 6. The pan stands above the level of the bottom of the furnace, and is accessible by means of steps. The melted fat can be run off through a tap near the bottom of the pan.

In large establishments, especially in inhabited districts, tallow melting in open pans is prohibited by the authorities, and the use of closed vessels is enjoined. A number of these appliances are described and illustrated in the following pages.

TALLOW-MELTING PLANT DESIGNED BY TONCOU.

The inodorous tallow-melting plant devised by Toncou is depicted in Figs. 7 to 9. The installation comprises sixteen pans A, each of which is fitted with a hood B (Fig. 9), together with a tubular superstructure and a manhole C for filling and emptying the pan. The vapour catchers (hood, etc.) B are connected with a draught flue H, about 30 in. high and 26 in. wide, which conveys the vapours under the white-hot dome of a small furnace (situated directly beneath a shaft E, which is about 110 ft. high), where they are completely consumed. The whole of the furnace fires are connected with the aforesaid shaft by a common flue F. In

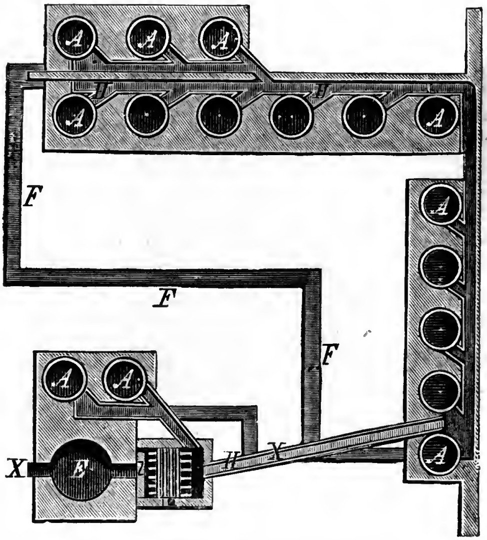

FIG. 7. Tallow-Melting Plant Heated by Direct Fire and Fitted with Deodorising Furnace.—A, melting pan ; B, hood ; C, manhole ; D, furnace for each pan ; E, vapour catcher ; F, flue common to all the furnaces ; G, supplementary furnace ; H, draught flue leading to G ; J, draught hole ; K, grating ; L, fireproof arch ; M, register.

very large works a draught hole J is provided, through which air enters and dilutes the vapours, which then pass through a grating K into the furnace C, the products of the combustion going on in the latter streaming through a grating into the fireproof arch L, and thence into the shaft. The hearth of the furnace G is 36 in. wide and 47 in. long. Coke fuel is employed here in order to reduce to a minimum the water vapour in the products of combustion. M is a vertical register or damper for shutting off the connection between the furnace G and the shaft E. In the same way the horizontal damper N serves to open up communication, when desired, between the flues H and F in order to divert the vapours from the pans whilst the fire is being kindled in G. By means of a second vertical damper O the furnace gases can be diverted through the fire G, the horizontal damper N being assumed as open for that purpose. This

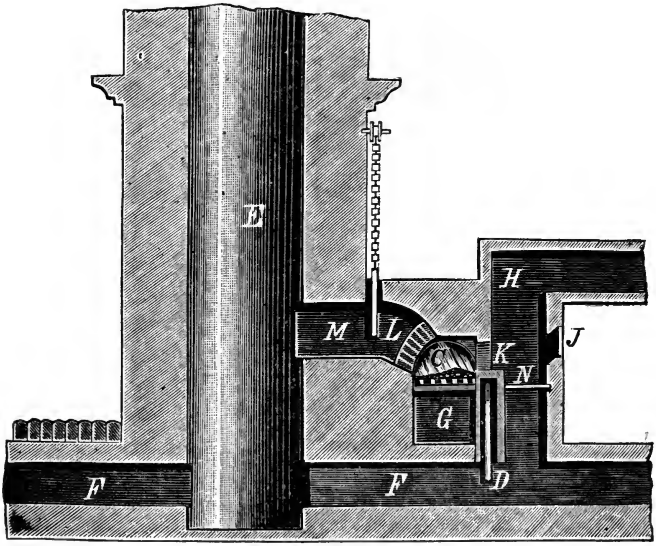

Fig. 8. Tallow-Melting Plant with Direct Fire and Deodorising Furnace.

arrangement presents the great advantage that the vapours and gases to be burned need not pass through the fuel, the place where the coal is consumed being distinct from the chamber wherein the actual destruction—combustion—of the gases is effected, so that, since pure air alone is admitted to the fuel, the fire can be made stronger or reduced at will. It goes without saying that the gratings K and L must be made of fireproof material (firebrick). This notwithstanding, the brickwork easily becomes damaged on account of the large quantity of moisture contained in the vapours.

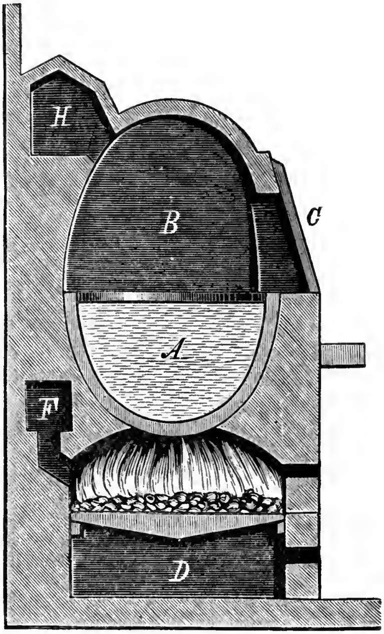

Fig. 9. Vertical Section of a Melting Pan.

Tallow-Melting Plant for Sulphuric Acid Method.

In order to obviate the numerous inconveniences attendant on the melting of tallow in open pans, and the great expense of large installations for working without smell, a practice has latterly arisen of melting tallow with the assistance of dilute sulphuric acid. An apparatus designed by Vohl for this purpose is shown in Fig. 10.

This consists of a lead-lined, cast-iron pan A, with cylindrical cover B and lid C, fitted with a mica plate D. A similar plate is fitted in the door E, and by this means inspection of the course of the operation proceeding inside the pan is facilitated. At night an artificial light is placed over the mica plate in the lid C. Mica is selected for these windows on account of its greater durability and security as compared with glass. The door E serves for the admission of the tallow and hermetically closes B, besides serving for withdrawing the greaves left on the grating at the bottom of the pan when the operation is terminated, after the tallow has been run off through the tap F and the acid liquor through G. The gases and vapours generated in A during

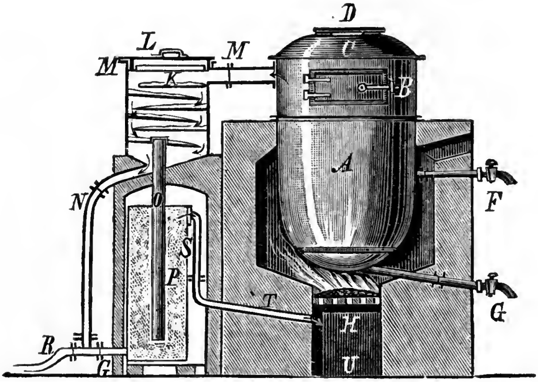

Fig. 10. Tallow-Melting Plant with Direct Fire (for Acid Treatment).—A, lead-lined cast-iron pan; B, cylindrical cover; C, domed lid; D, mica plate; E, door; F, outlet tap for tallow; G, tap for drawing off the acid liquor; H, hearth; J, pipe leading from pan to condenser; K, condenser box; L, lid; M, packing round the rim; N, outflow pipe; O, effluent for the easily condensable gases; P, condenser; Q, outflow pipe; R, outflow; S, outflow pipe for the permanent gases; T, flue; U, ash-pit.

the melting process pass through the pipe I to the condenser K, which is closed by a lid L packed around the edge M. Inside, the box K contains a number of inclined platforms covered with slaked lime. The box itself is made of wood impregnated with tar and asphalt. The condensed water runs away through the pipe N and forms in the swan-neck R a water-seal preventing the escape of vapour. The uncondensed gases and vapours issue from K *viâ* the pipe O into the lead-lined condenser P, which is filled with coke or pumice, impregnated with sulphuric acid, and the accumulated liquid runs off at the bottom through the pipe Q to the discharge pipe R, the permanent gases, etc., being finally led through the pipe S into the conduit T which debouches in the ash-pit U below the hearth of the furnace H where they are consumed. These gases can be delivered underneath the fire without any fear of reducing the draught, since they have been mostly freed from water in the condenser. The ash-pit U is fitted with an iron door by means of which a powerful draught can be induced for exhausting all the gases from the apparatus and carrying them to be consumed in the furnace. V is a funnel leading to the shaft and effecting the removal of the furnace gases.

In working this apparatus 20 parts of water previously mixed with ½ to 1½ parts of concentrated sulphuric acid are employed for each 100 parts of tallow to be melted. The sulphuric acid serves to effect the chemical decomposition and unlocking of the cells.

Wilson's Tallow-Melting Apparatus.

In the Wilson apparatus (Fig. 11) the steam enters through the perforated pipe G beneath the false bottom. The plate F fits tightly over the aperture E and the vessel is charged with tallow to two-thirds of its capacity. The steam pressure may be as high as 3½ atmospheres, a pressure which is maintained during ten hours. The condensed water collects beneath the false bottom and can be drawn off when required. The melted tallow runs away through the taps P P, and the greaves are finally removed through the aperture E.

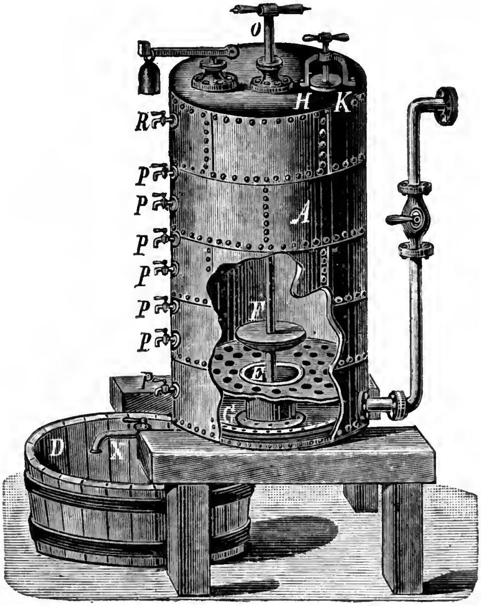

FIG. 11. Wilson's Tallow-Melting Apparatus.

GELLHORN, FLOTTMANN & CO.'S STEAM APPARATUS FOR TALLOW MELTING.

The fat to be melted is introduced into the melting pan A, through the neck, and rests on a grid B covered with fine filter cloth. The pan is situated in the basement, and the neck projects through the ground floor, an arrangement economising both time and labour in charging the pan. The latter is constructed of strong sheet-iron, jacketed with a tin case and slag wool lagging to prevent loss of heat by radiation. When the melting pan A is filled with crude fat water is poured in until the charge is covered, and the neck is then closed by a steam-tight lid.

Steam is conducted from the boilers C through the pipe D into the melting house as far as the pan A, where it passes down the two vertical branches E and F (fitted with valves G, H), the former of which extends almost to the bottom of the pan. To start the process the valve G is opened and admits steam (at a pressure of 3 atmospheres) into A below the grid B, whereby the water is first raised to the boil and

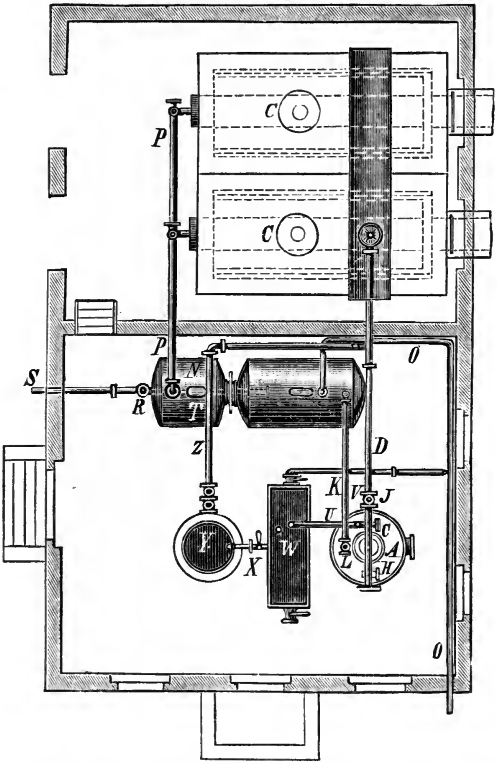

Fig. 12. Gellhorn, Flottmann & Co.'s Steam Apparatus for Tallow Melting. (Ground Plan.)

the fat to melting-point. The operation lasts five hours, during which time the boilers have of course to be refilled several times, so that the steam pressure continually recedes and it may happen that the pressure of steam in the boiler becomes less than that in the pan. To prevent the steam escaping from the latter back into the boiler by way of the feed-pipes E, D, a back-pressure valve J is affixed in D. A

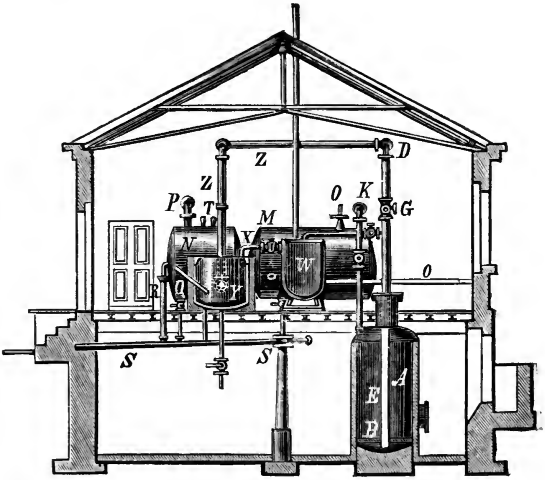

FIG. 13. Gellhorn, Flottmann & Co.'s Plant. (Section through Melting House.)—A, melting pan; B, grid with filter; C, boilers; D, steam pipe; E, F, branch therefrom to A; G, H, valves in pipes E, F; J, back-pressure valve; K, pipe to condenser; L, valve in K; M, condenser; N, receiver; O, water pipe; P, pipe conveying the gases to the furnace; Q, R, discharge pipes; S, general outflow pipe; T, manhole; U, pipe from A to W; V, valve in pipe U; W, clarifying vat; X, conduit from W to Y; Y, clarifying pan; Z, steam pipe leading to Y.

and D are also provided with pressure gauges to enable the pressure to be observed. When the differences of pressure are considerable the valve G is closed. Also at the end of one hour the valve G is shut and the valve L in the pipe K opened, whereupon steam and the malodorous gases evolved by the crude fat pass, in company with contained globules of fat, from A into the condenser M, which, together with the attached receiver N, is half filled with cold water. The pipe K is continued within the condenser M and debouches below the level of the water therein. Sufficient water is supplied by the pipe O to condense the vapour and fix the malodorous gases in the water, whilst the uncondensed gases pass with the fat globules and warmed water into the receiver N, and the gases that do not remain in the latter then pass through the pipe P to the back of the firebridge in the boiler fire where they are consumed. The inclined tube V in the receiver N serves to keep the water level in M and N constant by drawing off a quantity of warm water equal to that of the cold supplied and delivering it into the pipe R, which discharges it through the common outfall S into the open air, where it can be mixed with soil for manure.

The fat accumulating in time in the receiver N is removed through the manhole T. Taps leading to the outfall pipe S are fitted to the receiver and condenser in order to draw off their contents when they have to be emptied and cleaned.

Condenser, receiver and melting pan are built of strong sheet iron. When the gas is all removed the supply of water to the condenser is arrested, and the pan A disconnected from the condenser by closing the valve L. G being reopened, fresh steam is admitted into A, and the crude fat is again melted, this time for four hours, whereafter G is once more closed and the vapour and gas again passed through the condenser as already described. When the gauge on the pan shows that all the pressure is removed, A is closed and left for an hour, during which period of repose the preliminary clarification of the melted fat from the admixed solid residue and dirt is effected. The valve H in the pipe F being then opened, steam enters the upper part of the pan and presses on the surface of the fat there floating on the water; and when the valve V is opened the fat and water are forced through the pipe U into the clarifying vat W, the water entering first and being followed by the tallow, which is freed from the solid residue and coarser particles of dirt by the filter B, these latter being removed from A through the lower opening, which at other times is tightly closed. The clarifying vat W is of sheet-iron and has the largest possible surface; here are separated the particles of dirt, part of them sinking to the bottom and part forming a thin scum on the surface of the fat. After remaining at rest in this vat for six to eight hours the fat is then gradually floated upwards by means of water, admitted through the pipe O, until it runs off through the tapped pipe X into the clarifying pan Y, the water and deposited dirt in W being drawn off from the bottom. The vessel W is covered in, the vapour which enters when the mass is forced over from the pan A escaping through a pipe extending into the open air above the roof. The clarifying pan Y is a wrought-iron jacketed pan, open at the top, constructed to stand the working pressure (3 atmos.) of the steam in A, and lagged with lead and slag wool to prevent radiation. Before the fat is admitted the pan is partly filled with clean cold water, and then, when the fat is in, the mass is gently boiled by means of steam admitted into the jacket space from the pipe D *viâ* Z. After treating in this way for an hour, during which time the scum is taken off, the valve in the pipe Z is closed, and the steam and water of condensation are run off through S.

When the mass is so far cooled that it begins to set, the tap in the pipe leading from the bottom of the clarifying pan is opened and the contents drawn off, the water and dirt first, and then the purified fat, which is delivered into the transport casks. In the hot season cold water from O is passed into the jacket space around the pan and assists the setting of the fat.

By means of this apparatus perfectly pure tallow is produced.

LOCKWOOD AND EVERITT'S STEAM PLANT FOR TALLOW MELTING.

The advantages of this plant consist chiefly in the complete destruction of the evil-smelling vapours injurious to health, and in the security of the apparatus against explosion, the fat being gradually melted in a digester. The apparatus consists of two parts, *viz.*, a melting pan and a furnace for consuming the evolved gases and vapours, these two parts being connected by a pipe J. The pan, or digester, which contains the fat to be melted, consists of a steam-tight cylindrical vessel A surrounded by a jacket B. In order to make the apparatus extremely firm—since it has to bear a temporary pressure of 7 atmospheres—the top and bottom of the cylinder are connected by iron stays and the jacket with the inner cylinder by stay bolts, in addition to which the steam pipe C, which serves to regularise the temperature of the charge of fat, also assists in strengthening the pan. Under the vessel, which is mounted on feet, is a furnace, the hot gases from which pass through flues G cut in the brickwork in such a manner that the gases come in contact with as large a surface as possible of the pan and finally escape into the chimney. The melting pan is filled by way of a manhole E, and the residual skin, greaves, etc., are removed through an opening F. The removal of the liquid fat is effected by an exhaust pipe M turning on a swivel joint D, and fitted at the end with a strainer to keep back extraneous matters, the other end leading to an outlet pipe U, through which the fat, forced upwards by the pressure in the pan, is delivered to any convenient spot. The gases and vapours generated during the melting of the crude fat are led through the junction pipe J to the Argand furnace (as the inventor designates this portion of the apparatus). Here the gases at first traverse a system of heated tubes O and then issue through four burners P arranged symmetrically around the furnace, and are there mixed with atmospheric air and burned.

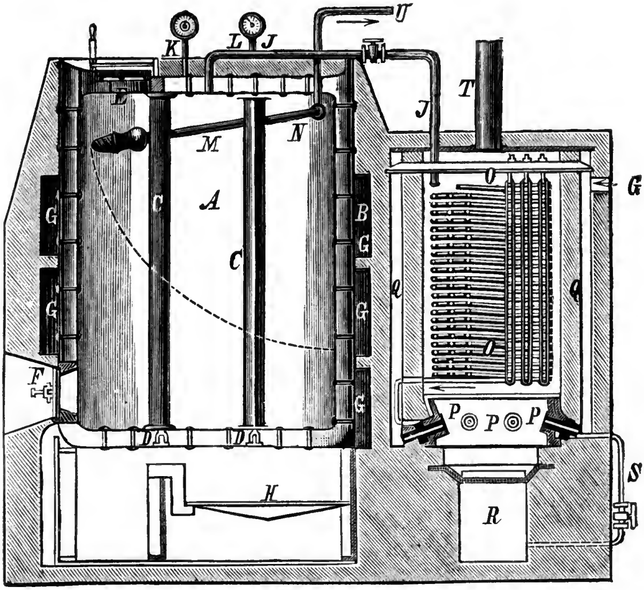

FIG. 14. Steam Plant for Tallow Melting.—A, sheet-iron pan; B, jacket; C, steam pipe; D, stay rods; E, manhole; F, outlet; G, flue; H, hearth; J, pipe leading to furnace; K, pressure gauge of steam jacket; L, pressure gauge of digester; M, exhaust pipe with strainer; N, swivel joint; O, system of tubes; P, burner; Q, opening and air chamber; R, hearth; S, tube; T, flue; U, outlet pipe.

The products of combustion in ascending surround the spiral O and escape into the chimney T. The air requisite for combustion enters at the upper part of the furnace, at G, into an air chamber enclosed in the brickwork, where it is heated, and thence passes to the burners below. In order to increase the draught a small tube S conducts heated gas under pressure into the space below the hearth R. With this description the working of the apparatus can be explained in a very few words. After the jacket B has been filled with water up to a level with the top of the flue, the charge of fat is placed in the digester, care being taken that the exhaust pipe M is first raised to its highest position and fixed there. Simultaneously with the closing of the feed-opening the Argand furnace is kindled, and as soon as a moderate amount of pressure is indicated by the gauge K the tap in the pipe J is opened and the gases allowed to escape to the combustion furnace, which must in the meantime have become hot enough to ensure the destruction of the malodorous gases. The heating of the melting pan is so regulated that the pressure inside the pan does not exceed 2½ atmospheres and that in the jacket space not more than 4 atmospheres. In order to ascertain when the melting is complete, samples may be taken from time to time through the pipe M. The capacity of this digester is generally 7½ tons. When the residual tissues are intended for fodder they are dried at night in the pan itself, a low fire being kept up in the combustion furnace.

STEAM APPARATUS FOR TALLOW MELTING.

A simple form of tallow melter heated by steam is given in Fig. 15.

The apparatus consists of a pan covered with a hood which is fitted with an effluent pipe. The tube through which steam at a pressure of several atmospheres is admitted is wound in spiral form in such a manner that the upper tier of the coil is situated at a level about one-third the height of the pan, the others being directed progressively downwards until the lowest one makes its exit at the foot of the vessel. Since the steam enters at the top of the coil and condenses to water therein, it is necessary to give the coil such a pitch that the water can run away freely. At the commencement of working the steam is regulated so that water alone issues from the lower extremity of the coil, and the steam current is allowed to act until the crackling sound caused by the evaporation of water from the greaves is heard inside the pan.

To facilitate the removal of the melted fat the bottom of the pan is rounded and is fitted with a pipe, above which is a sieve supporting the greaves, these latter being afterwards removed through a lateral opening (covered by a screwed lid) on a level with the false bottom. A water gauge, fitted at the side of the pan, enables the height of the melted tallow in the vessel to be observed. The pan is also lagged with wood to prevent the radiation of heat.

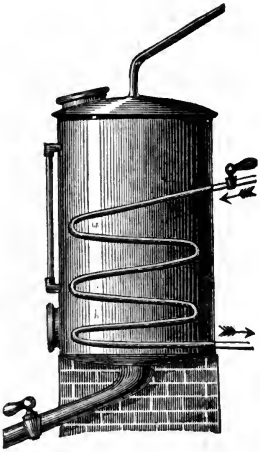

FIG. 15. Steamer for Melting Tallow.

A slow current of steam may be passed through the coil even while the pan is being charged, the current being turned on more fully, as already described, when the pan is closed. Directly the fat is melted the steam is shut off, the fat being then run away through the pipe at the bottom of the vessel, which is refilled with tallow after the greaves have been cleared out.

RIVOIR'S STEAM APPARATUS FOR TALLOW MELTING.

This apparatus, displayed in Fig. 16, works without smell, and the liquefaction of the fat is effected by steam under a pressure of from 3 to 5 atmospheres. The pan is made of wrought iron, with a riveted, rounded bottom, and stands upright on a wrought-iron frame. In the lower fourth of the cylinder two perforated false bottoms are fixed at a little distance apart, the fat to be melted being laid on the upper one, which is readily accessible from outside through a lateral aperture closed by means of a bow and screw and situated on the same level with the false bottom. This opening serves for clearing out the greaves.

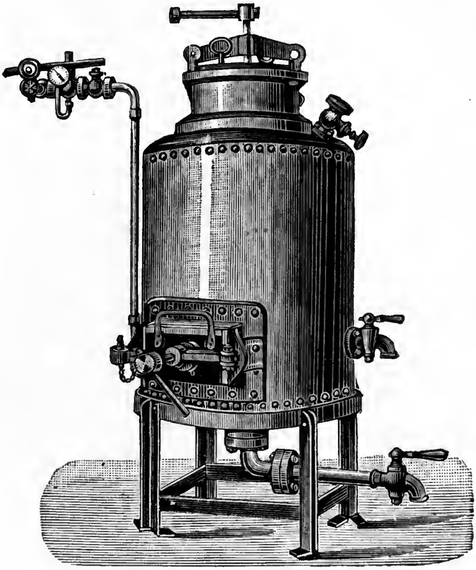

FIG. 16. Steam Apparatus for Tallow Melting (W. Rivoir, Offenbach-on-Main).

Between the false bottoms there is a lateral tap for drawing off the melted fat.

Beneath the lower false bottom is situated the steam coil, and below that again, in the deepest part of the pan, are the tap and pipe for emptying the vessel completely. At the top of the apparatus is a manhole, fastened by a bow and screw, through which the pan is filled, and entered for cleaning; and an escape pipe for the vapours is also situated in the top of the vessel. When the apparatus is connected with a steam supply working at a pressure exceeding 5 atmospheres it must be provided with a safety valve, pressure gauge, reducing valve and back-pressure valve between the pan and the feed-pipe. Where steam is not available the apparatus can be modified so as to be set in brickwork and generate the steam required for the melting process.

For working with indirect steam, *i.e.*, without the steam and fat coming into direct contact, the maker supplies jacketed pans well tinned inside, the heat being then applied by a steam coil situated in the space between the two walls of the pan. A cold water coil is also provided, so that the temperature can be regulated as desired. The interior fittings comprise a vertical pipe and a draw-off tap as in the case of the single pan, a tap for completely emptying the vessel being placed, with its attached pipe, centrally, at the lowest point in the bottom. The pan itself is supported on a wrought-iron stand.

In order to accelerate the melting process stirrers are provided which squeeze the lumps of melting fat between arms. These stirrers are made of well-tinned wrought iron and are easily taken out for cleaning. Motion is imparted from a driving pulley above and a pair of cone wheels, and they can be arranged for driving either by hand or power.

By reason of their simplicity and great capacity Rivoir's melting pans have proved exceedingly useful and are preferred by experienced melters to more complex and less practical systems.

For melting good quality tallow (*premier jus*, edible fat) Rivoir makes simple, round, wooden vats heated by direct steam, which is admitted through a coil at the bottom. A draw-off tap for the melted fat is placed at a moderate height above the foot, the fat being delivered to this tap by a jointed pipe, an arrangement which allows the clear fat to be drawn from any level within the vat. A cleaning-out valve is fitted in the bottom, the aperture being large to enable the residue to be removed from the vat with ease and the latter swilled out with water. All the ironwork coming in contact with the fat is well tinned.

O. HEINTSCHEL'S TALLOW-MELTING, CLARIFYING AND FILTERING APPARATUS FOR CONTINUOUS WORK.

The apparatus shown in various points of detail in Figs. 17 to 20 consists of three parts: the melting pan A, the clarifier B and the filtering vessels C^1 C^2 C^3.

The melting pan is a cylindrical vessel with a funnel-shaped bottom, which, as shown in Figs. 17 and 18, is jacketed, the intermediate space between the walls containing a heating apparatus H^1, composed of coiled or transverse pipes or pouches. In the axis of this pan is situated a vertical filtering cylinder F^1 (Fig. 19), projecting through both lid and bottom of the pan and fitted with stirrers and overhead driving gear. Being open below and projecting through the bottom W, this cylinder communicates with the second chamber B, unless closed by means of a slide or trap, etc., V, whereby the two chambers can be isolated. Close to the filter tube, in the deepest point of the bottom of A, is a second opening O (Fig. 19), so that a valve adjustable from outside enables A and B to be connected with or shut off from one another. The filtering cylinder has a perforated jacket, whereby the fat introduced into A through the feed-opening E is, after being melted by the warm air in the double walls or heating apparatus, enabled to filter through the openings in the said cylinder. When V (Fig. 18) is open the fat drains away and collects in B. In order to increase the filtering capacity the tube F may be replaced by perforated filter tubes, the perforations being made only on the side of the tube opposed to the direction of movement of F, in order to prevent the clogging of the filtering surface. For the same purpose a slide, perforated with apertures corresponding to those on the cylinder, can be mounted thereon and by being moved up and down be made to clear away any fibres, etc., attaching themselves to the apertures; or a scraper

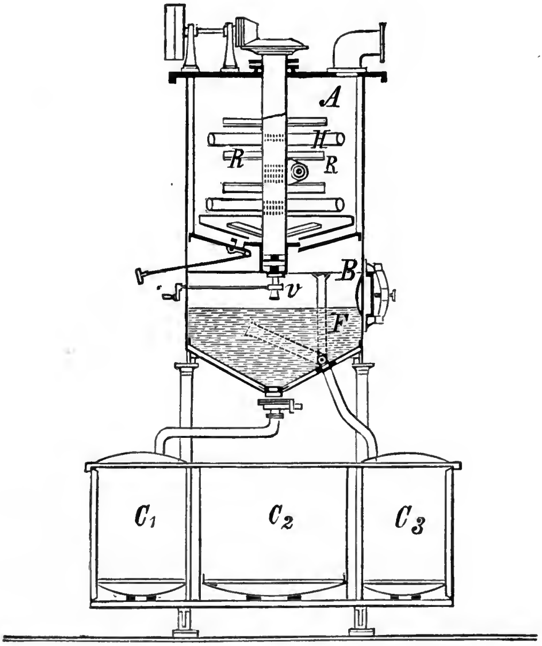

Fig. 17. Heintschel's Tallow-Melting, Clarifying and Filtering Apparatus. (Front Vertical Section.)

may be affixed to part of the apparatus so that its cutting edge rests on the filter cylinder and scrapes off any adherent matter during the rotation of the cylinder.

The clarifying chamber B is situated underneath or by the side of A, and, like the latter, has a deepened bottom and a heating apparatus. At the deepest point in the bottom it is fitted with a closable aperture, and near this a telescopic or hinged tube (adjustable from the outside) or else a number of taps at different heights. When a sufficient quantity of melted fat has been run off from A into B then the chambers are isolated by closing the aperture of communication. In consequence of their different specific gravity, the various grades of tallow, as well as the admixed particles of fibre and water, quickly separate in layers, the better, lighter grades being at the top, the others successively lower, and the water and fibrous particles weighted therewith, lowest of all in the deepened bottom B; so that by suitably adjusting the draw-off tube, or by way of the taps, definite grades of melted fat can always be run off from above downwards and conducted by the flexible tube D into the clarifying vessels.

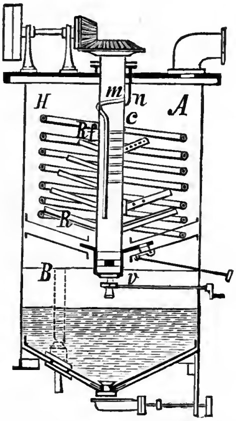

FIG. 18. Heintschel's Apparatus. (Details of Melting Pan.)

The solid constituents (greaves) collecting, in the course of the continuous melting process, in the bottom of the melting chamber A, as well as water, blood residue, etc., are drawn off from time to time through O into the empty clarifying chamber, where they are clarified, the hot liquid fats they still contain being removed through T ; and, finally, the less valuable, thick residues are withdrawn through O into the vessels placed underneath, where they can be subjected to further treatment. In this process, by means of the continuous series of operations performed in succession (melting, clarifying and drawing off), the capacity of the apparatus is far in advance of the old-fashioned plant as regards both the quantitative and qualitative results obtained. Moreover, this system possesses the additional ad-

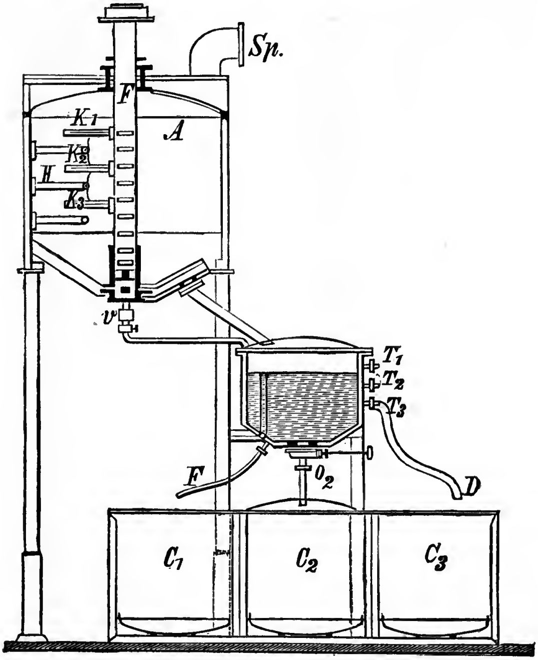

FIG. 19. Heintschel's Apparatus. (Lateral Section.)

vantage that by drawing off through the adjustable pipe B and collecting extremely uniform grades of melted fat in the corresponding clarifying vessels, a well-assorted class of goods is produced and the raw material utilised to the best advantage. In order to enable the separation of the fats to be effected according to specific gravity in the chamber A^1, another construction is given to the filtering cylinder. This is perforated with a convenient number of holes or slits arranged in rings at different heights and is provided with a well-fitting inner tube perforated to correspond.

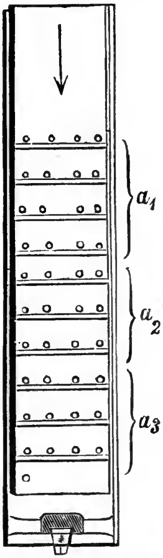

FIG. 20. Heintschel's Apparatus. (Filtering Cylinder.)

Thus, for example, if the fat is to be separated into three portions at equal intervals of height, three equidistant rows of rings are provided. By raising or lowering the tube, *e.g.*, through a distance equal to one-third of the interval between the rings, the sifting rings opposite the one layer are brought into juxtaposition, the openings in the other two being covered and thereby closed. By this means a qualitative separation of the melted fats can be effected even in the melting chamber A, uniformity of quality being thereby more effectually ensured.

Fat-Extracting Apparatus with Corrugated Bottom.

The apparatus shown in plan in Fig. 21, and in side and front view in Figs. 22 and 23 respectively, is designed for melting fat or extracting it from fatty substances. It is enclosed on all sides and heated internally by steam passing through several series of parallel pipes *a* arranged at different heights, the walls being covered with insulating material to prevent radiation. The arrangement is such that the steam

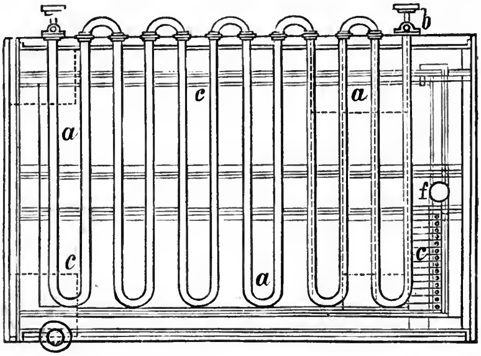

Fig. 21. Fat-Extracting Apparatus with Corrugated Bottom.

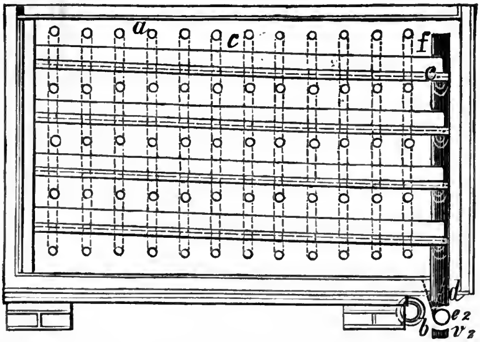

Fig. 22. Apparatus with Corrugated Bottom. (Side View.)

from a common feed-pipe *c* enters each series at the same time, so that a uniform temperature is maintained throughout all parts of the tubes and apparatus. In order to increase the influence of the heat, radiated from the pipes, on the fat or fatty matter in the flat boxes *c*, and, with this object, to obtain the largest possible extent of surface, the bottom of the box is made of corrugated tinplate, an arrangement greatly increasing the area of surface exposed in comparison with a flat bottom. In the hollows formed by the corrugations are fixed semicircular or angular strips of iron, which are perforated all along the edges, so that the melted fat can run through into the channel formed by the iron strips and hollows of the bottom and run down to the front of the box, which is laid at an angle for this purpose. Not only is the draining of the fat facilitated by this arrangement but the impurities are also retained. The fat arriving at the front of the boxes runs down through apertures there into open channels *e*, which convey it to a vertical collecting pipe. In this case the corrugations extend to the front end of each box. Instead, however, of having a channel *e* underneath, the front edge of the box may be inclined towards the centre of the apparatus, and when this is the case the corrugations

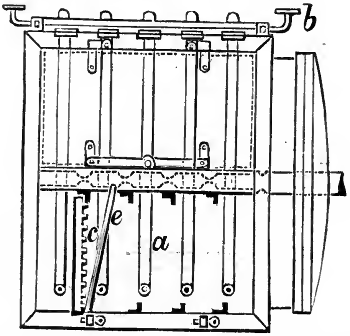

FIG. 23. Melting Apparatus with Corrugated Bottom. (Front View.)

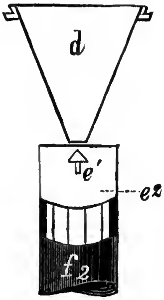

FIG. 24. Arrangement of Funnel.

do not extend quite to the edge, but a ledge sloping down towards the middle of the apparatus is attached thereto. The fat coming from the channels or boxes runs into this ledge and is conveyed therein to the centre of the apparatus. Under these ends are arranged stays (fastened near the collecting pipe) which catch the fat and lead it into the collecting pipes, from whence it passes to the collecting vessel. Another method of draining the fat from the front end of the boxes consists in allowing it to fall direct into a channel at the bottom of the apparatus, in which case the ends are arranged stepwise, the upper ones always projecting beyond those successively lower, so that the fat can drop direct from each to the channel e^2, which slopes down towards the middle and terminates there in a collecting pipe. To prevent the fat splashing as it falls into the channel the latter is made in the shape of a funnel, with an angle as acute as possible, so that splashing is out of the question. This channel may either be provided with a small lateral opening discharging into a concave channel e^2, or may have an opening at the bottom, under which a partition wall e^1, covered with a shed roof, is arranged.

Instead of fitting the boxes with corrugated bottoms as described, ordinary melting vessels may be employed, corrugated plates being fitted either on the bottom or at a slight distance above. The fat is placed on these plates so that the melted fat flows down the channels and collects in the bottom of the vessel, to be then drained away in a suitable manner.

Extraction Plant.

As already mentioned, the extraction process, which in the vegetable fat and oil industry is of considerable importance, is only employed in isolated cases for animal fats, the nature of the latter being different. Bone fat is the chief fat recovered by extraction, and rationally conducted establishments either extract the fat alone from the bones and treat the residual matter in other ways, or work up the bones completely in one operation. The forms of apparatus described in that section of the author's work *Vegetable Fats and Oils* dealing with extraction processes (*q.v.*) are also applicable for the treatment of bones as well as of the residue (greaves) from fat-boiling works, whilst the plant now described is intended specially for the extraction of bone fat only.

Dr. Ahrens' Apparatus for Extracting Bone Fat.

Latterly it has been proposed to replace the benzene almost universally employed for depriving bones of their fat by carbon tetrachloride, which is a powerful solvent of fat, has a constant boiling temperature, is uninflammable and leaves behind no unpleasant smell in the fat after saponification. If, however, carbon tetrachloride be used in the ordinary fat-extracting apparatus a remarkable phenomenon is observed: the fat is either black or very dark brown in colour. This results from the decomposition products of the carbon bisulphide always present in commercial tetrachloride, the bisulphide forming, with the ammonia in the bones and iron in the blood, sulphocarbonates, which split up into carbonates and sulphur compounds, which are always dark coloured and remain behind in the extracted fat after the removal of the solvent by evaporation. On the other hand, chemically pure carbon tetrachloride cannot be employed, on account of its high price.

Nevertheless, the present process and the apparatus therefor enable the ordinary tetrachloride, contaminated by carbon bisulphide, to be used, the above-named objection being obviated. The process consists in depriving the bones of their fat in an open extractor fitted with two perforated false bottoms and a cooler, the cooling water of which covers the bones and the solvent. The ammoniacal vapours expelled from the bones during the heating of the solvent, form, with the accompanying air, bubbles, which ascend through the liquid and carry with them the carbon tetrachloride. In order to separate these bubbles of air, ammonia and tetrachloride into their constituent compounds, a number of sieves arranged spirally and connected by fine sieves are fitted in the cooler, against which the bubbles impinge, whereby, in conjunction with the action of the water trickling down the partition walls, the tetrachloride is deposited in the form of specifically heavier oily drops, which are reconducted to the extractor, whilst the air escapes and the ammonia is retained by the cooling water. In the appended illustrations Fig. 25 shows the general plan of the apparatus and Fig. 26 a modification in the construction of the cooler affixed to the top of same. The method of working the form depicted in Fig. 25 is as follows: After the extractor A has been filled with bones through the upper manhole

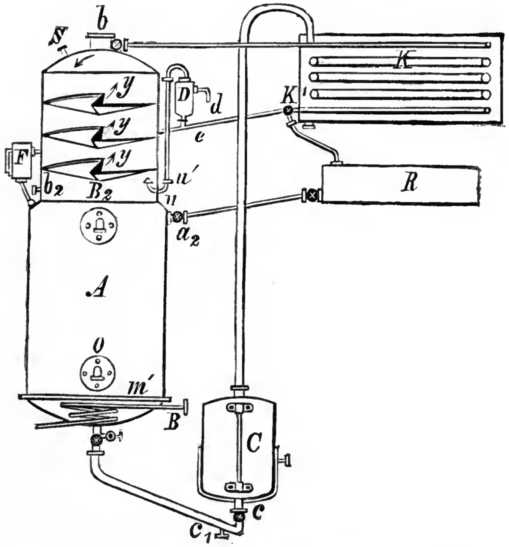

FIG. 25. Ahren's Bone-Fat Extracting Apparatus. (Cross Section.)

O so that they reach nearly up as high as the upper false bottom *m* (which prevents their floating), the manholes O and O^1 are closed and carbon tetrachloride is run in from the storage vessel R until the bones are covered and the solvent attains the level of *m*, which can be ascertained by means of the windows. The tap a^2 of the pipe supplying the solvent is then closed and water is poured into the cooler B through a neck *s* until the level of the upper manhole is attained. Meanwhile the valve a^1 of the overflow pipe *u* is closed, the manhole cover being off. The solvent in A is then heated to boiling-point by a steam coil B^1 under the lower grating

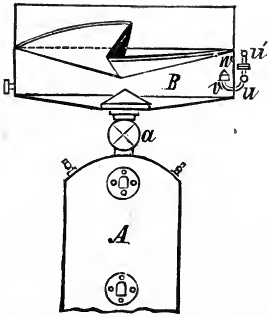

FIG. 26. Ahrens' Bone-Fat Extracting Apparatus. (Cooler.)

(false bottom) *m* and dissolves out the fat contained in the bones. The vapours of carbon tetrachloride evolved during the boiling ascend into the water in the cooler, are there condensed and fall back into A, to then renew their course. At the commencement of boiling, air and ammonia are given off from the bones and carry some tetrachloride with them. The partition walls Y in the cooler B, which serve to separate the bubbles of gas, run in a spiral direction upwards, inclining towards the axis of the cooler and being connected together by fine sieves. The ascending bubbles impinge on the spiral walls and are diverted laterally, passing from one compartment into another until they burst. By the impact of the bubbles on the partition walls and their passage through the sieves, the tetrachloride is, under the concomitant action of the cooling water, deposited, and, with the assistance of the stream of water trickling from S, rolls down the steep plane until it reaches the lowest point, whence it is diverted back into the extractor. The ascending ammoniacal vapour is dissolved by the cooling water and is conveyed away through the overflow pipe *u* for further treatment. This overflow pipe is fitted with a cover in the vicinity of its embouchure in order that the descending tetrachloride may be diverted sideways. Any tetrachloride carried away, notwithstanding this arrangement, is removed by a separating funnel D fixed at the lower extremity of the overflow pipe, where it falls to the bottom and is conveyed through a short pipe *d* into the conduit *e* and into a circulation vessel, whilst the cooling water runs away from the separating funnel.

When, after several hours' exposure to the tetrachloride, the bulk of the fat is dissolved, the solution is run off through the tap *a* into the still *c*, and the extractor re-charged (after closing *a* and opening a^2) with solvent from the vessel B to the same height as before. The solvent is distilled off in C and is condensed in the cooler K, whence it flows through *e* and E back into the extractor. The circulation vessel E, which is connected to the cooler K on the one hand and with the extractor on the other, serves to control the progress of the operation, in that the liquid distilled from the fat flows into it (E) from the cooler and thence into the extractor. For the purposes of this control a water-gauge glass is attached to the circulation vessel, so that by observing the fluctuations of the level of the liquid in the gauge the course of the operation can be judged.

The extraction of the fat is gradually effected in the foregoing manner, and the solvent becomes progressively poorer in fat. As soon as a sample taken from c^1, between the extractor and the still, is found to be free from fat the extraction is finished, and the expulsion of the solvent from A is proceeded with. This is accomplished by admitting direct steam into A through pipes a^4 by closing the taps a and c, turning the steam valve k^1 back to k, drawing off the cooling water through the pipe b^2, closing the manhole lid b and then opening the tap b^3 of the pipe leading to the cooler. Hereupon the solvent passes over into the cooler K, where it is condensed and returned to the vessel R for use over again, whilst the fat is freed from the last traces of solvent in the still C and is finally drawn off. Several of these extractors can also be united to form a battery, and the solvent remaining in the first extractor at the conclusion of the operation may be transferred to the second extractor ready filled with bones, an arrangement saving both time and steam. Moreover, at the commencement of operations the (closed) extractor can be connected with an air pump in order to exhaust the bones of air and gas and thus reduce the amount of gas evolved; this without deviating from the principle of the invention.

In Fig. 26 the cooler B is modified in so far that it is flattened at the base and expanded laterally and connected with the extractor A by a shut-off valve a^5. The cooler may be also jacketed or fitted with a worm tube to reduce the temperature.

By the method of extraction in open vessels with carbon tetrachloride—boiling at 65° to 78° C. according to its degree of purity—the employment of a uniform low temperature, and consequently the production of good fat, is rendered feasible, the decomposition of the solvent being, furthermore, prevented, since all the evolved gases and salts are removed by the supernatant cooling water. In addition to this the glue in the bones is greatly protected by reason of the low temperature employed and of the insolubility of the glue in tetrachloride.

J. KALECZOK'S BONE-FAT EXTRACTING APPARATUS.

The vessel *a*, which is fitted with a perforated false bottom, is filled with bones, and the opening *b* closed. Hereupon, the hemispherical steam pan is placed under steam pressure, and the tap *d* in the feed-pipe supplying the solvent (benzine) opened. The benzine flows from the feed-pipe *b* on to the hemispherical surface, where it is vaporised, and ascends, along with the vapours given off by the bones, through the pipe *e* into the condenser *f*. The condensed solvent and the water (the steam from the bones) arrive at the chamber *h*, whence the water runs off through the pipe *i*, and the benzine continues on its way through the chamber *g* and thence through the feed-pipe back to the vaporising pan. The fat extracted from the bones, accompanied by a small quantity of the solvent, runs away from *a* through the pipe *k* to the

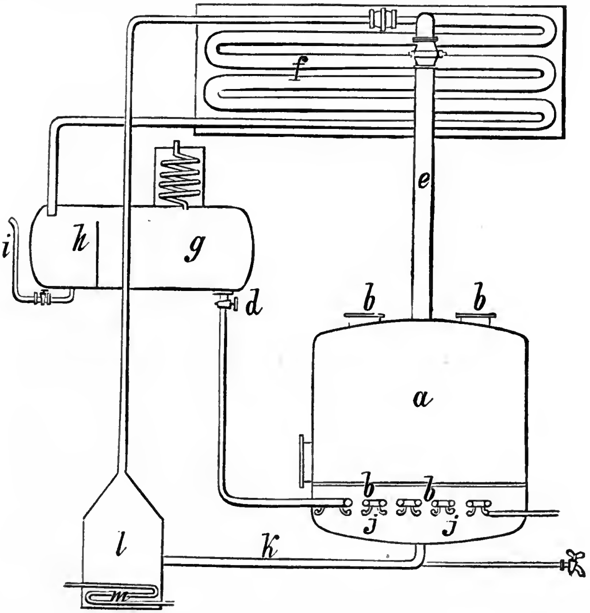

FIG. 27. Kaleczok's Bone-Fat Extracting Apparatus.

vessel *l* containing the steam coil *m*. The steam pipe in the bottom of *a* is arranged as a spiral coil.

A screen fitted over the benzine supply pipe prevents the extracted fat from coming into contact with the hot steam pipe. A number of small apertures in the benzine pipe permit the outflow of the solvent on to the hemispherical surface of the vaporising pan. The effluent liquid is immediately vaporised, so that overflow is impossible. A flange, which serves to support the feed-pipe, forms the connection between several branch tubes.

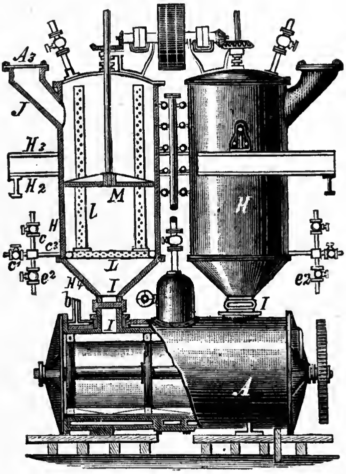

Fig. 28. The Holdhaus Fat-Extracting Apparatus.

THE HOLDHAUS APPARATUS FOR EXTRACTING FAT AND DRYING THE RESIDUE.

The apparatus displayed in Fig. 28 serves for the extraction of fat from tissue and also for drying the residue. It consists of a drying cylinder A, provided with an arrangement for warming and manipulating the contents. A series of cylindrical vessels H is superimposed, and these communicate with the drying cylinder by apertures I in the bottom. These vessels are also provided with suitable openings for the admission of the material into the recipients, and each is fitted with a workable piston M, which can be forced downwards by the mechanism provided for that purpose and squeezes the liquid out of the boiled material. The liquid is then drawn off through the tap e^2. The vapours from the vessels H are condensed and removed by means of one or several condensers and suitable pipes. The pressed material is then transferred from the vessels into the drying cylinder, where it is freed from moisture.

Meikle's Apparatus for Extracting Bones, Seeds, Fish, etc.

The cylindrical vessel (Fig. 29) is divided into an upper and lower chamber by means of a perforated partition supporting a layer of filtering material, and is also fitted with a hollow lid, conical projections on the under side of which facilitate an evenly distributed dropping of the solvent. The hollow space within the lid can be heated or cooled by means of the contained steam and cold water pipes. The steaming chamber is steam jacketed and is also fitted with a small steam jacket or steam disc on the inside. The lower chamber is provided with a similar heating appliance, and both are fitted with revolving stirrers mounted on a hollow shaft, which extends through the partition, and is perforated with lateral apertures.

When the apparatus is to be used the raw material is placed in the upper chamber and impregnated with the solvent, which is forced in, under pressure, through a supply pipe perforated to ensure uniform penetration. The resulting fatty solution then filters through the partition and heat is applied to the lower chamber, whereby the solvent is vaporised and ascends, not through the filter, but by the easier passage, *viz.*, the hollow shaft, and escapes through the lateral apertures thereof. The vapours are condensed by the cold water pipe in the hollow lid, and the conical projections present the advantage of preventing the condensed liquid from collecting at one place, in that it drops uniformly from all the points formed by these cones, and so impregnates the material evenly. The extraction, therefore, proceeds continuously, and the stirrers can be set in action when convenient. When the operation is completed the hollow lid is no longer cooled, but heated like the rest of the apparatus, and the vapours then pass to the condenser. As soon as the extracted oil or fat is removed, the apparatus can be filled with a fresh charge of material.

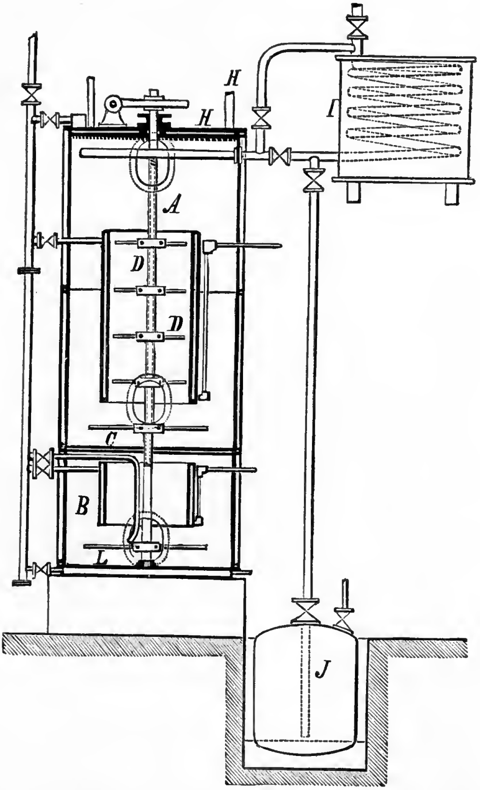

FIG. 29. Meikle's Extractor for Bones, Seeds or Fish.

APPARATUS FOR EXTRACTING FAT AND GLUE.

E. J. Machalski of Brooklyn has constructed an apparatus for this purpose, the details of which are as follow : At the bottom of the vessel destined for the reception of the materials to be treated is placed a steam disc for heating same. Three pipes debouch into the vessel, one of them conveying the (vaporised) solvent, the second removing the excess of this vapour to the condenser and the third supplying water. Underneath the vessel are placed recipients for collecting the fat and glue, and there is also a battery of cisterns for concentrating and purifying the liquid glue, so arranged, one above the other, that the liquid runs through the series by gravitation, to be finally forced up through a pipe into special clarifying vessels.

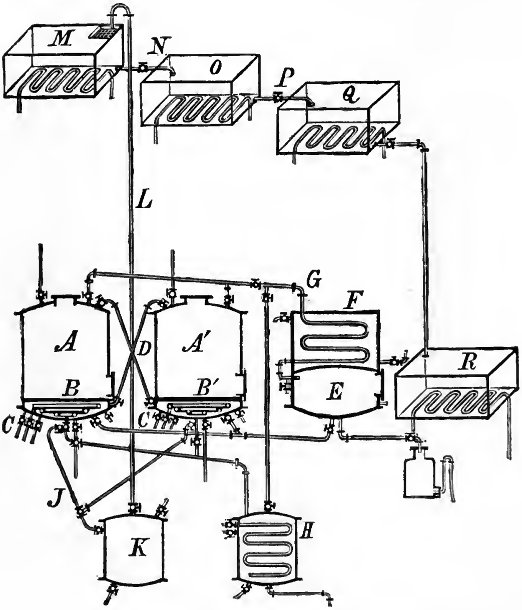

FIG. 30. Machalski's Extractor for Fat and Glue.

Schweitzer's Extraction Plant

for animal (and vegetable) materials is composed of an extraction cylinder fitted with manholes at the top and side, a condenser, an evaporator and the vessels destined to receive the condensed solvent. The pipes and valves effect the following combinations: Extractor with condenser, evaporator and condenser, condenser and storage vessel. The apparatus produces a perfectly dry residue, because the solvent used has a much higher boiling-point than that of water.

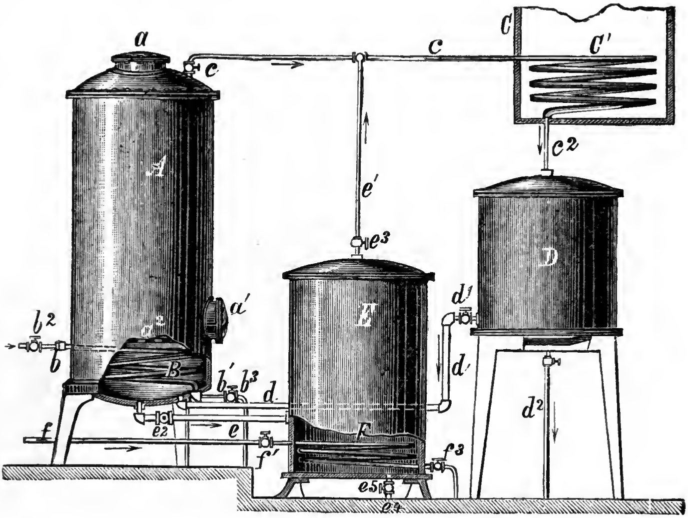

Fig. 31. Schweitzer's Extractor for Animal Material.

The method of working is as follows: The materials are placed on the grating in the extractor, and the solvent is admitted. Then all the communications are shut off except that between the extractor and condenser, and the solvent is heated by steam pipes nearly to boiling, whereby chiefly water vapour is evolved. The fat is dissolved and falls through the grating, and when the extraction is terminated the fatty mixture is transferred to the evaporator and heated to boiling, whereupon the connection leading to the condenser is opened and the fat or oil afterwards drawn off. If the residue is to be freed from the small portion of adherent solvent it is then heated to boiling in the extractor, and the evolved vapour is led into the condenser.

W. O. Robbin's Extractor.

This apparatus (Fig. 32) is described by the inventor as consisting of a cylinder (for containing the material to be extracted) traversed by a perforated tube for the admission under pressure of the solvent or of air. In the interior of the cylinder runs, on a guide way, an accurately fitting carriage, for the reception of the raw material, and provided with a slip extending from top to bottom. The operation is effected by filling the carriage with the material under treatment, the latter being then exposed to the action of the selected solvent, passed into the cylinder under pressure. When the extraction is completed the excess of vapour is driven over into the condenser by air, whereby the press residue is simultaneously dried, and the fat run off.

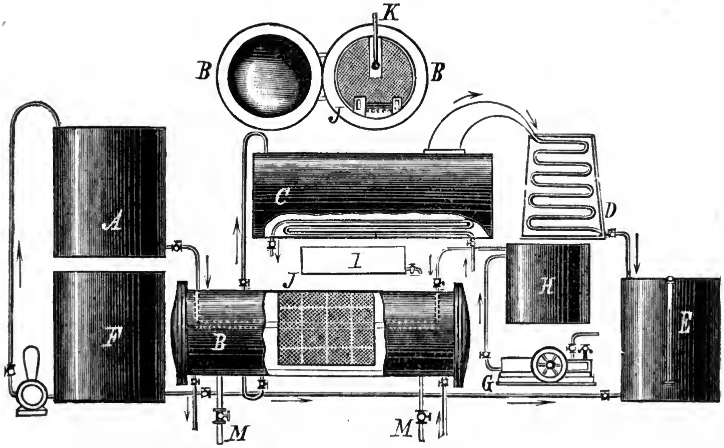

Fig. 32. W. O. Robbin's Extractor.

Perfected Extraction Apparatus.

In the various other extraction processes the separation of the fat and the concentration of the crude glue liquor have to be effected in separate, independent vessels, an arrangement entailing special attendance on each. In the present case, however, the entire process, *viz.*, the steaming of the raw material, the recovery of the pure fat and the concentration of the glue liquor, is performed at one time and in the same apparatus. To this end the pipe *d*—as can be seen in Fig. 33—through which the liquid flows from the vessel A to B, is provided with a fairly wide aperture *i* at the upper end, whilst the lower end reaches nearly down to the bottom of the vessel. On opening the valve *e*, the mixed liquid and vapour pass over from A into B, and the vapour is conducted away through *i* and the pipe *h* to the condenser C, whilst the liquid portion runs quietly down the pipe *d* and separates at the bottom of the vessel into fat and glue liquor, without, as hitherto, being mixed up together and heated by the current of steam.

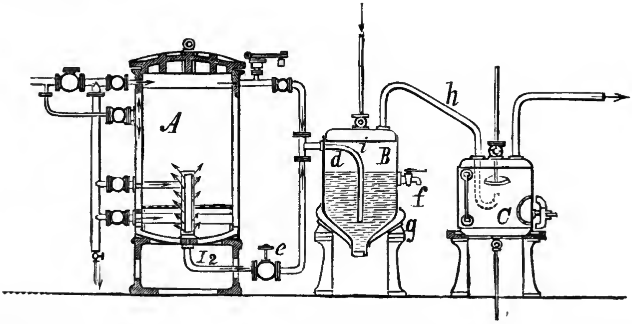

Fig. 33. Apparatus for Recovering Fat and Glue from Animal Residues.

The separation of the steam can also be effected in another way. Thus, for example, the pipe *d* is diverted sideways into a boiler, in the lid of which is placed a wide, open pipe, whilst from the lower part of the pan the pipe *d* extends nearly to the bottom of the vessel. The mixture of steam and liquid flowing in tangentially through the pipe *d* streams along the walls of the pan, whereby the steam is separated from the liquid, the latter flowing downwards through a pipe *d*, whilst the steam escapes through an upcast pipe *l* and passes thence through the pipe *h* to the condenser C. In the completed form a plate is provided, against which the mixture of steam and liquid, entering laterally through *d*, impinges, and is separated into these components, the liquid running down through a pipe, whilst the steam passes round the plate and escapes upwards through the aperture. The same separation can, of course, also be effected by other means. After the complete separation of the fat from the glue liquor has been accomplished in the lower part of the vessel B, the former is drawn off through the tap *f*, and the residual glue liquor concentrated in B itself. To this end a heating apparatus, *e.g.*, a steam jacket, is placed at the lower extremity of the vessel B, and by this means the glue liquor is raised to boiling-point and thoroughly concentrated. The vapours thereby expelled pass through the pipe *h* to the condenser C, where they are completely thrown down, the concentration being in this manner effected entirely without smell. The nitrogenous dry matter in the glue liquor is left as a residue and may be removed by a suitable opening provided in the vessel B.

This new apparatus consequently offers the great advantage that the steaming process in A is in nowise influenced by the concentration in B, and both operations can be carried on at the same time; only for that purpose the condenser must be of sufficient capacity to cope simultaneously with the vapours delivered by A and those evolved from the glue liquor in B.

Whereas, in earlier forms of apparatus, the products consisted of dried bones (or meat), fat and glue liquor, in the present instance they comprise merely fat and the whole of the solid substances present in the carcase. By the abolition of the easily decomposable glue liquor, an important hygienic advantage is, however, gained without the other favourable points of the process—especially as regards absence of smell—being impaired.

PRESSES.

Presses play a merely subordinate part in the recovery of animal fats and oils, whilst in the case of vegetable substances of this nature they form the chief mechanical appliances used. For animal fats they are employed in the following instances :—

1. For expressing the residue from the fat-rendering process (greaves : see Greave presses) ;
2. For pressing tallow to separate it into its solid and liquid components ;
3. For pressing the blubber from marine animals.

Greave presses are simple spindle presses, but, for the other purposes mentioned, hydraulic presses are mostly used, and these will now be generally described :—

The hydraulic press is founded on the principle of the uniform transmission of pressure throughout liquids in closed vessels, and such presses consist of two separate parts—the press proper and the pump. The first is composed of : a press plate terminating below in a piston (moving in the movable cylinder contained in the lower enclosed portion of the machine) ; a head plate ; and (as a rule) four pillars connecting the press head with the base of the apparatus. In this latter is also placed the connecting piece effecting a junction between the press cylinder and the pump cylinder. The pump is of the plunger type, with two cylinders of unequal diameter, the larger becoming automatically disconnected when the pressure attains about 20 in., the further pressure required being effected by the smaller cylinder alone. The minimum of pressure varies for each press, and the overstepping of the maximum pressure is prevented by the automatic action of a safety valve. The pressure produced by the pump is transmitted through the liquid—water, glycerine or a mixture of both—and also through the connecting valve and the liquid in the press cylinder, and exerts on the piston of the latter a force per unit of space equivalent to the pressure per unit produced by the pump (small) piston. As soon as the desired pressure is attained the connecting valve is closed, so that the pressure in the press cylinder may not be influenced by any leakage in the pump. In order to reduce the pressure a second valve in the connecting gland is opened and the liquid returned to the pump chest without passing through the cylinder. In this manner the valve of the pump is preserved on the one hand, and on the other the same liquid is used over and over again, no renewal, beyond the small amount wasted by leakage, being required.

Hydraulic presses of both vertical and horizontal form are employed, the former being, however, the kind mostly used in tallow-melting works. In those employed for pressing fat, a number of press plates of trough or box form are superimposed, so that the lower part of each engages in the upper part of the one next below and presses the material contained therein, the outflowing fat being conducted into a common channel. For warm pressing, the press plates are fitted with appliances for steam heating, swivel pipes permitting the introduction of steam at one side of the cast- or wrought-iron plates and the removal of the condensed water on the other. Where several hydraulic presses are at work in the same room, they can be all fed from the same pump; but where they are in separate rooms, then working by accumulators can be practised with great advantage.

A hydraulic tub press is shown in front and side view and in section in Figs. 34 and 35. The press consists of the press cylinder A and the piston B, situated between two pillars on which the troughs E slide by means of rings. These troughs carry a solid iron plate and are surrounded below by a channel *d d* for collecting the expressed fat. The boxes G containing the fat to be treated have double walls and are provided with a circular row of apertures at the top of the inner wall. These boxes are filled with fat, which may have been previously cast in moulds of suitable size, and are then covered over with a horse-hair cloth. When the press is started the troughs E are pressed into the boxes G, the liquid fat runs out of the openings below the upper rim of the latter and collects in the channels *d*. As soon as the operation is completed the pressure is removed, whereupon all the parts of the apparatus recede into the positions they

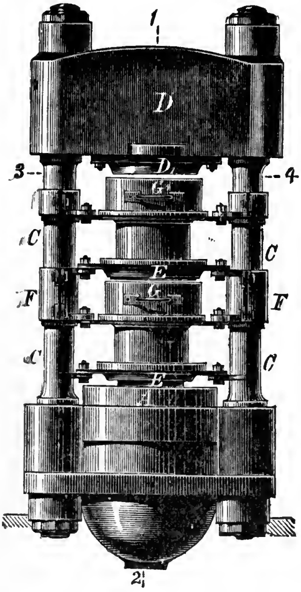

FIG. 34.

(Front View.)

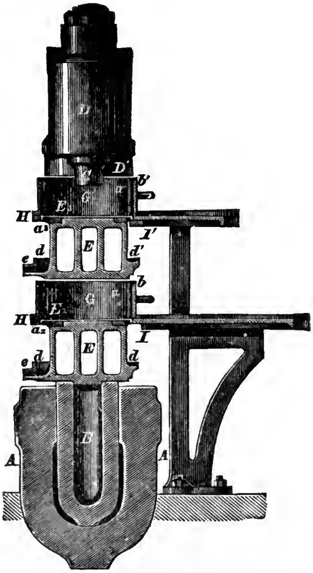

FIG. 35.

(Side View and Section.)

Hydraulic Tub Press.

occupy in the drawing. The boxes G are taken out on to the table and replaced by others ready filled with fat, so that the time the press is standing idle is reduced to a minimum.

Among the new forms of hydraulic presses prominence is due to those of Brinck & Hübner of Mannheim, by reason of their important advantages, consisting of :—

1. Quicker and simpler service with greater capacity ;
2. Abolition of expensive press cloths ;
3. Production of uniform cakes of fat ;
4. Great durability without attrition of expensive parts.

The general construction is as follows: In the press are situated four, six, eight or ten wrought-iron or steel rings, one above another, and each fitted with a finely perforated steel bottom. Between each pair of rings is placed a cast-iron or cast-steel press plate, convex on the upper surface but flat on the under face. On these plates, which are guided by the pillars of the press, rails are affixed for carrying the press rings, and on these the latter slide when being placed in, or removed from, the press; and, in addition, each press plate is provided with a large encircling channel to catch the expressed liquid fat. The presses are filled by simply laying over the perforated steel bottom of each ring a horse-hair, wool or felt cloth, covering this with the fat to be pressed, and the latter, again, with a second similar cloth. When all the rings are full the pressure is turned on and the fluted upper face of each plate forces its way up into the ring next above, the liquid fat running out through the horse-hair cloth, the perforated steel plate and the grooves in the press plate, into the channel.

When the fat is caused to flow uniformly from the entire surface of the cake it has only a thin layer to traverse, and thus runs away rapidly and yields a thoroughly uniform press cake. In pressing particularly heavy cakes the rings become too heavy to be lifted out, so on this account the presses are fitted with two lateral frameworks and a double set of rings, and as soon as one set of rings containing the

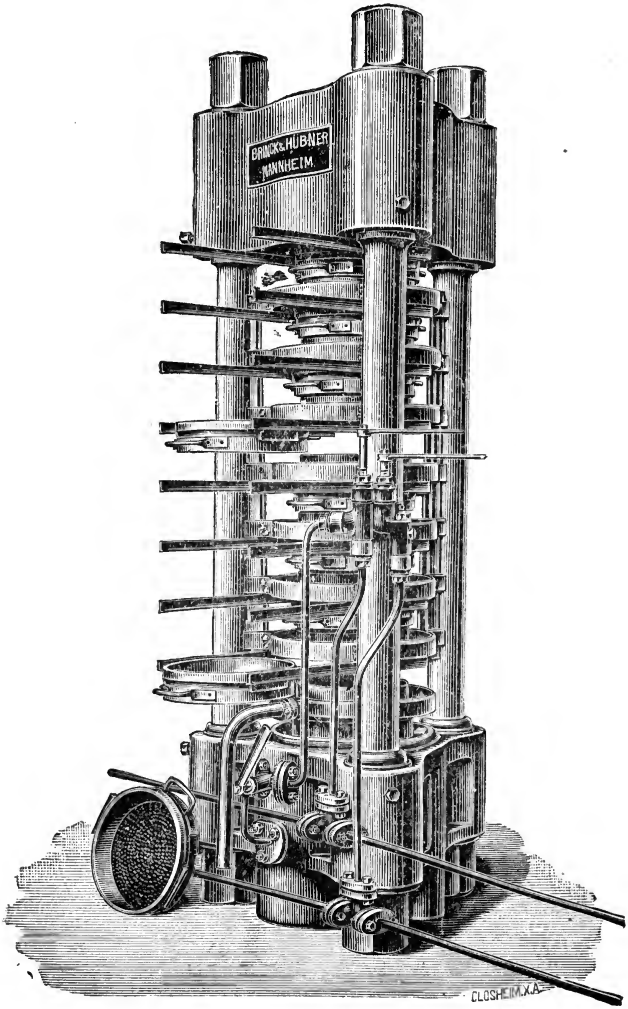

Fig. 36. Brinck & Hübner's Hydraulic Ring Press.

pressed fat is drawn out on to the side frame to be emptied and refilled, the other (filled) set is pushed into position from the other side frame, so that the operation is simple and goes on without interruption.

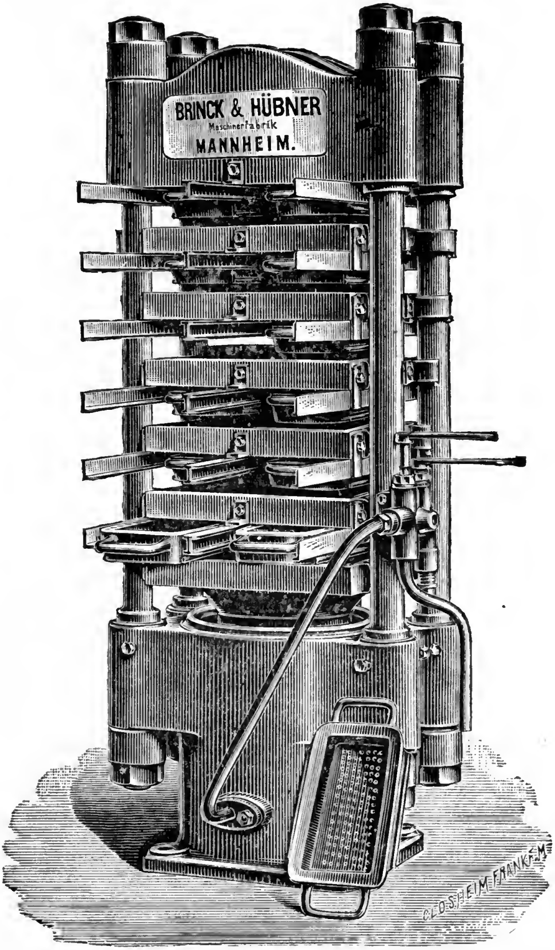

FIG. 37. Brinck & Hübner's Hydraulic Box Press.

By making suitable boxes in place of the rings the cakes can be made in square or trapezoid form of suitable size. All presses are provided with appliances for heating each part with steam or hot water, and, as each mould rests between two heated plates, the temperature is uniform and results are attained that no other system of pressing can yield. The presses are constructed for pressures of 300 atmospheres and over, and the cylinders, pillars and nuts are of cast steel.

When it is a question of pressing fat without heat, simple presses without boxes, rings or tubs are used; such a press being shown in Fig. 38. The fat is packed in sacks and trimmed on the plate of the press, and when the loading is completed pressure is applied, whereupon the fat runs out and is caught in a suitable manner. The pressing of blubber is generally effected in very primitive presses worked by levers. Of course a quantity of the product is lost, but Rose, Downs & Thompson of Hull have constructed a screw

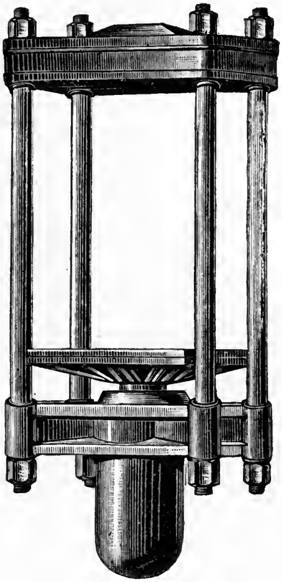

FIG. 38. Hydraulic Margarine Press.

press for fish oil highly suitable for this purpose (Fig. 39), only moderate pressure being required. The shaft carrying the screw spindle is fitted at either end with fast and loose driving pulleys, that on the one end being driven by a straight and the other by a crossed belt, so that the plates of the press can be raised or lowered by steam power, and also, when necessary, stopped at once. The actual press is placed within a steam-jacketed chamber, the outer walls being of wrought iron strong enough to stand the pressure, whilst a door of similar construction and also heated by steam forms a secure and hermetical seal during the time the press is at work. The charge is packed in sacks and laid between metal press plates. The press can also be constructed to work with hydraulic pressure, and for certain purposes the jacketing chamber is omitted.

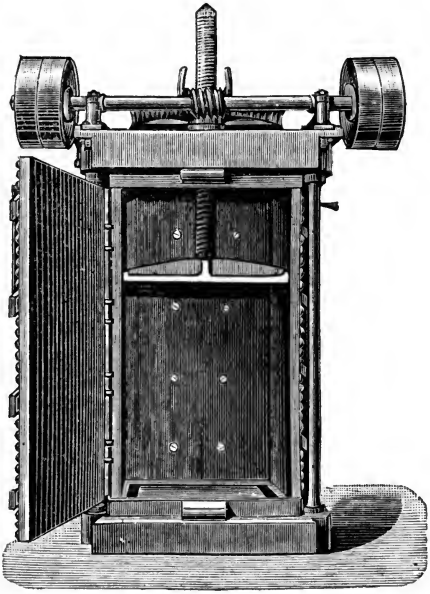

Fig. 39. Fish Oil Screw Press (Rose, Downs & Thompson).

FILTERING APPARATUS.

The animal fats do not require such a thorough-going purification as vegetable products of the same class. For one thing the animal fats are generally solid and therefore have to be brought into the liquid condition before they can be purified or filtered; and, on the other hand, they are mostly put to technical uses, whereby they sustain a certain amount of alteration, *e.g.*, saponification or melting, which purifies them. The fats destined for alimental purposes are prepared by repeated pressings, and since—unlike the vegetable fats—none of the solid and extraneous matters in the animal fat escape through the press cloths, a further purification appears superfluous.

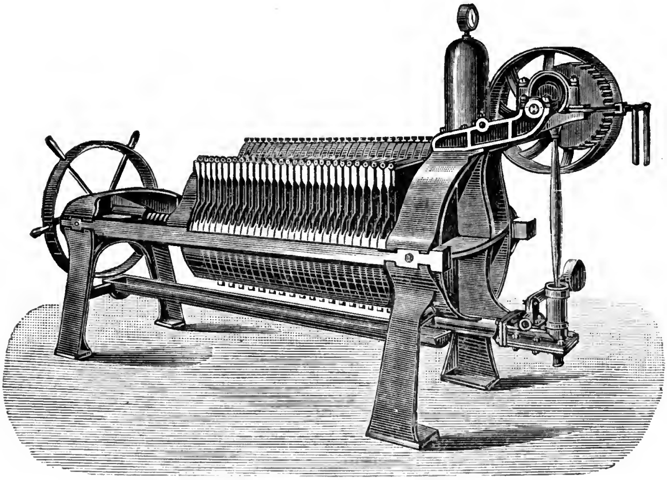

FIG. 40. Filter Press Worked by Power (Rose, Downs & Thompson).

As a matter of fact, it is only the liquid fats of the animal kingdom, the fish oils, that are purified by filtration when required for alimental or better-class technical purposes. The reader is therefore referred for information on the subject of filtering apparatus to the author's work on

Vegetable Fats and Oils, and on the present occasion mention will be made of only a single appliance, *viz.*, a

FILTER PRESS FOR LIQUID ANIMAL FATS (FISH OILS).

Fig. 40 depicts a filter press particularly suitable for filtering fish oils, and capable (with thirty-six compartments) of treating twenty tons of oil with ease; moreover, the press can be worked every day for a week at a time without requiring cleaning. As soon as the separate divisions have been fitted with the filter cloths and the screw tightened up the machine is ready for work. The material to be filtered can be fed direct and the filtrate removed by pumping. The press is self-contained, requires no setting and can be easily fitted up, all that is required to make it ready for work being connection with a source of power, direct or through intermediate shafting.

ANIMAL FATS AND OILS:

RAW MATERIALS, PREPARATION, PROPERTIES AND USES.

ALLIGATOR OIL AND CROCODILE OIL (ALLIGATORÖL, KROKODILÖL).

Raw Material.—The amphibia known as alligators or crocodiles—that is to say, the fat contained in their flesh.

Preparation.—No particulars are obtainable, but probably by melting like tallow.

Properties.—Alligator oil is of the consistency of ointment, semi-fluid, reddish in colour, with a sp. gr. of 0·928, and contains 32 per cent. of margarine and stearine, 1·5 per cent. of free oleic acid, 60 per cent. of olein and 0·02 per cent. of iodine.

Crocodile oil is of a reddish colour, but more liquid than alligator oil. A mixture of both is met with in commerce.

Uses.—Both kinds are technically employed in tanning.

BUTTER.

Raw Material.—Cow's milk, as being the richest in fat of the secretions of all mammals.

Preparation.—Milk contains a fat—butter—which is precipitated when the milk is exposed to strong and continuous agitation. The phenomena have been explained by Soxhlet as follows : The fat forms along with the other constituents of the milk a perfect emulsion of small drops of very different sizes. In this condition the fat is endowed with the property of remaining liquid at temperatures whereat the butter obtained from same would be solid. This peculiarity results from the superficial tension proceeding from the extremely thin layer of serum (also known as the serum envelope) lying within the sphere of attraction of the globules. In the same way as molten masses in general can be made to congeal by vibration, so in the manufacture of butter a few drops are first made to solidify by mechanical concussion and increase in size by contact with liquid fat. The larger congealed fat drops thus produced attach themselves by impact to others, and so, finally, the greater part of the fat becomes collected into small mulberry-like adherent masses separable from the other constituents of the milk by skimming. Therefore, in the process of butter-making, the fat drops, on the one hand, are congealed, and, on the other, the solidified particles are united to a coherent mass.

In point of chemical composition milk is a highly complex substance. The following constituents occur (though in quantities varying between certain limits) in all sound milk : casein, albumin, fat (butter), lactose (milk sugar), salts, extractive matter and water. The proportions vary, even in one and the same animal, according to the mode of feeding, age of the individual, etc., within certain limits, so that a universally applicable analysis of milk cannot be given.

The subjoined figures are, however, the mean of a large number of analyses :—

Cow's Milk.	Average Percentage.	Limits of Variation.
Water	87·5	83·0-90·0 per cent.
Solid (dry) matter	12·5	10·0-17·0 ,,
Containing :—		
Fat (butter)	3·4	0·8-8·0 ,,
Casein	3·2	2·0-4·5 ,,
Albumin	0·6	0·2-0·8 ,,
Lacto-protein	0·1	0·08-0·35 ,,
Milk sugar	4·5	0·3-6·0 ,,
Ash	0·7	0·7-0·9 ,,

The greatest care and cleanliness are essential in the preparation of butter, by reason of its extreme liability to absorb extraneous flavours and odours, and the best fresh milk immediately undergoes an unfavourable alteration under the influence of even very small quantities of fermentative spoiled milk. For this reason storage chambers for milk have to be selected with great care, and attention devoted to keeping them scrupulously clean.

Very widely divergent methods are employed for preparing butter from milk. In one the milk is divided into two portions :—

1. A cream very rich in fat, this being taken for churning ; whilst

2. The second portion (poor in fat), the skimmed, blue thin milk, is put to another use, or the entire milk is churned.

In separating the cream from the milk three different methods are practised :—

1. The milk is left to itself as a layer, some 4 in. deep, in shallow pans (shallow setting) until the cream collects as a consistent mass on the surface.

2. The milk is set in high vessels, 16 to 20 in. in height (deep setting, or Schwartz process), and kept at a temperature of 2° to 4° C.

3. The milk is separated almost instantaneously in special centrifugal machines (milk separators) into skim milk and cream.

The first method is the oldest, and is still practised in many dairies. The vessels employed are either of wood, well-fired stoneware, enamelled cast iron or pressed tinplate. When the cream has finished rising it is skimmed off with a flat spoon or separated from the skim milk by means of special appliances. In small dairies basins are often used from which the skim milk can be poured away direct, the cream being retained by a cream catcher. When kept for some time, or when the cream is a long while in rising, the products—skim milk and cream—arrive at the initial stages of acid fermentation.

With regard to No. 2, this method presents the advantages of keeping the products sweet, requiring fewer vessels, occupying less room, and being independent of the state of the weather. On the other hand, the cream is thinner and more bulky; consequently the yield of butter milk is increased.

No. 3. In "separating" milk the liquid, enclosed in a rapidly revolving drum, is, by the action of centrifugal force, divided in such a manner that the specifically heavier milk is impelled against the outer walls, whilst the specifically lighter cream is forced towards the centre. This process enables the work to be carried on uninterruptedly and produces none but sweet cream. Among the various types of cream separators that of Laval has proved the best in practice. In this apparatus the fresh milk runs continuously in, whilst the cream and the skim milk leave the machine by two separate outlets, these products being obtained in such a condition that the cream may be either sold as a luxury of diet or worked up into butter, whilst the residual milk makes an excellent cheap food. The separator consists of an oval hollow vessel A, of best Bessemer cast steel, and holding about $1\frac{1}{2}$ galls., which is encased in a cast-iron housing and rests on the spindle K. This latter stands loosely in a wood bearing in a depression in the pivot *h*, which is driven by the small band pulley and intermediate gear at such a rate that it makes 6000 turns a minute, whereby the spindle and the receiver are carried round by adhesion. The central supply pipe *a*, with two lateral delivery tubes, is screwed in the bottom of A, and over this is slipped the tube *f* (leaving an annular space of about $\frac{1}{24}$ in.), the lower end of which is fastened to a ring which forms the bottom of the small chamber *c*; and over *f* again is placed the tube *d*, which expands below into a cup-shaped cover forming the upper part of the chamber *c*, the whole being joined to A by four screws. From the bottom of *c* projects the bent open tube *b*, reaching to the inner periphery of A. If now the milk be admitted through *a* into the receiver, which is running at full speed, it is forced with great power against the walls, the time required to fill A sufficing for the separation of the milk into its constituents, of which the

FIG. 41. The De Laval Separator. (Elevation.)

specifically lighter cream collects around the central supply pipe and is driven upwards as the supply proceeds into the narrow annular space between *a* and *f* and to the chamber *c*, whence it runs away through a pipe. The thin milk rises up through *b* into the small chamber *c* and thence through the opening between *d* and *f* into the chamber B, whence it escapes through a discharge pipe.

The Bechtolsheim "Alpha" separator, driven by power, will treat up to 460 galls. of milk per hour, leaving only about 0·2 to 0·3 per cent. of fat in the skim ; smaller machines are also made for hand driving, to separate 15 to 60 galls. per hour.

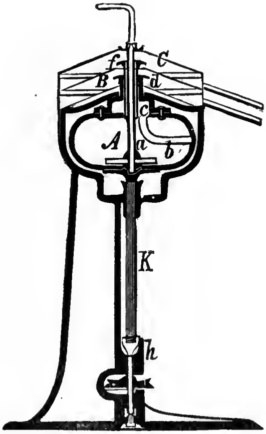

Fig. 42. The De Laval Separator. (Section.)

In Fesca's centrifugal machine the operation is not continuous. The milk enters through the funnel *a* into a roomy cylinder A running at high speed, whereby the cream is forced, in the direction indicated by the arrows, towards the centre, where it is retained by the cylinder *b*, whilst the thin milk runs away from the periphery of A through openings in the bottom, and, entering the jacket space B, is run off through the pipe C. At the end of about an hour the liquid escaping from C is not merely thin milk, but milk that is only slightly separated, owing to the chamber *b* being full of cream. When this is observed the driving belt *c* is slipped on to the loose pulley and the drum is allowed to empty itself. As the centrifugal force decreases the cream runs out into the jacket space and is caught in a separate vessel at C. When it is all out the operation can be re-commenced.

The separation of the cream is effected more readily at somewhat higher temperatures than it is in the cold, so that it is advisable to either put the milk through directly it comes from the cow or else to warm it up to blood heat. On the other hand, the keeping qualities of the butter improve in proportion as the milk after milking, or the cream after separating, is brought down to the desired low temperature, for which purpose special coolers are used, consisting of a cooling chamber for the liquid, surrounded by one or two series of tubes through which cold water is continuously flowing. The product is drawn off after a certain time into a vessel underneath.

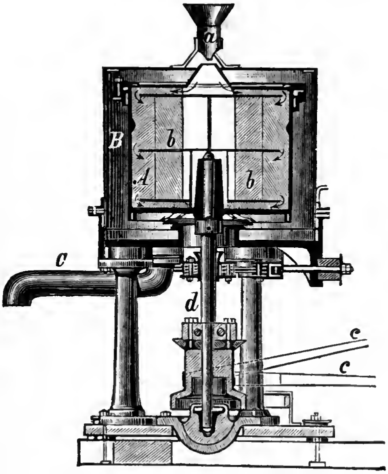

FIG. 43. Fesca's Centrifuge.

As we have already seen, sweet or sour cream is obtained as the raw material for butter-making, according to the system pursued. There is no difference in the yield of butter whether the cream be sweet or sour, but there is in point of flavour, sweet cream yielding a sweet, nutty-flavoured butter, whilst that from sour cream has a sour and (when the cream has been kept long) even a rancid taste. The cream temperature for butter-making should be about 15° C. in summer and 20° C. in winter. The principle of the process has already been discussed. It is necessary to subject the cream to powerful and uniform agitation, the regulation of which constitutes the aim of a large number of appliances, and as every year sees the introduction of new ones, it is impossible to refer to them all.

The types of construction may be divided into classes, according as the butter is produced by—

1. Beating (dashing),
2. Stirring,
3. Shaking.

As to which is the best the opinions of butter-makers widely diverge. So far as the constitution of the butter itself is concerned, it is immaterial which method is pursued, the only question being that of forming the butter in the shortest possible time and in the highest degree of purity.

Among the appliances may be mentioned: The percussion churn (farmer's churn) is the oldest but least recommendable, by reason of the great expenditure of force required; Lefeldt's rotary barrel churn; Davis' rocking churn; the roller churn; the Holstein barrel churn, etc.[1] Among those suitable for work on a large scale Rennes' butter machine should be mentioned; this belongs to the type of percussion and dasher churns.

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[1] *Translator's Note.*—There are many makers of these different styles of churns, those above being evidently intended by the author as typical examples.

The milk is placed in a box J so arranged that there is no difficulty in running in the cream and removing the butter, both being effected through the flap K. The buttermilk is drawn off through an opening at the bottom of the vessel, generally kept closed by means of a ball valve. The beating of the milk is accomplished by a pair of dashers P P alternately raised and lowered by eccentric gearing. A disc A with grooved rim rotates on a fixed axis and carries the two ropes *c c*, which are also connected with the rods T T attached to the dashers P P. A also carries an iron arm connected with the fly wheel G at F by a rod E, the pin F, forming at the same time the crank of the fly wheel. The distance from the centre of the guide disc to the point of attachment of the connecting rod with the iron arm being greater than the radius of F, A can therefore merely rotate through an arc the radius of which is double that of F, while F makes a complete turn. The arm is rigidly attached to the disc and therefore the latter can only make an alternating semicircular movement, during which the points at

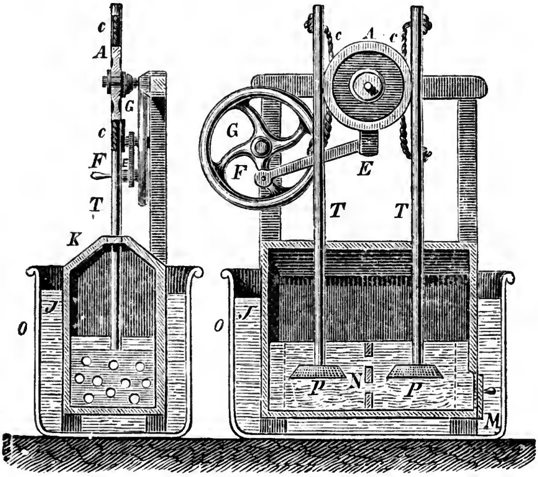

FIG. 44. Rennes' Butter Machine.

which the ropes *c c* are attached have a similar motion, *i.e.*, a semicircle, whereby the attached rods T T are caused to rise and fall alternately. These rods move vertically through suitable apertures in the cover of the box J, and since the ropes *c c* are placed exactly opposite one another the one rod T begins to rise at the same instant that the other rod commences its descent. A perforated partition N is placed between the dashers P P, and, finally, the cream chamber J is surrounded by a vat O which can be filled with hot or cold water as desired.

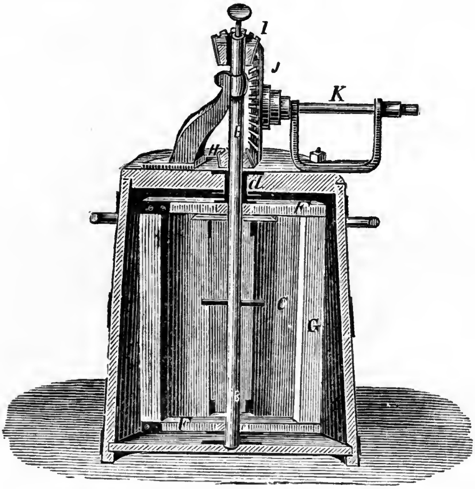

Fig. 45. Brochardt's Butter Machine.

Brochardt's butter machine (Fig. 45) belongs to the class wherein the separation of the butter is effected by the stirring produced by the vertical rotation of an axis. This machine consists of driving gear K, which, by means of wheels I and J, sets a shaft B in rapid motion. B carries a series of vertical dashers and also a pipe *d* connected with a toothed wheel H, which in turn is in connection with the wheel I. At the lower end of the tube *d* are fixed a number of horizontal rods F forming the spokes of a wheel, and a similar wheel is situated below and is connected with the upper one by the vertical dashers G. The shaft *c*, which is attached to the box of the lower wheel, is supported in a bearing in the bottom of the churn. There are thus in the machine two systems of dashers (G, C), both of them movable, though in opposite directions. This opposite motion, produced by the force acting on the two cone wheels H and I from the wheel J, causes, as can readily be understood, a very brisk movement of the cream in the churn, and quickly effects the separation of the butter.

The proposals that have been made for admitting air, or for adding acids or alkalis to the cream in the butter-making, in order to facilitate the rapid separation of the fat, have proved unsuitable.

The butter produced by one or other of these mechanical processes contains a large proportion (16 to 22 per cent.) of enclosed buttermilk, which causes the butter to quickly become rancid, unless thoroughly worked out. This buttermilk contains, when sweet cream has been used, both milk-sugar and casein in solution ; or, when the cream was sour, solid casein, in addition to dissolved lactic acid. All these substances are readily decomposable, the milk-sugar being converted into lactic acid by the lactic ferments present, and then causing the casein to curdle. On this account the cavities in butter prepared from sweet cream and not further purified very soon exhibit small lumps of curd together with a liquid tasting strongly of lactic acid.

After a short time, particularly in summer, the lactic acid is converted into the evil-smelling butyric acid, whereby the butter assumes a repellent taste and smell. When the butter has been made from sour cream, then lactic acid will be present ready-formed in the fresh butter, and the decomposition of this acid into butyric acid will occur much sooner than in the case of sweet-cream butter. The decomposition, once set up, extends also to the fat, and the butter will very soon assume a disagreeable, irritating taste and cheesy smell, which render it unfit either for eating or cooking purposes. Butter that has undergone such alteration can only again be rendered suitable for cooking by a carefully performed re-melting.

It is therefore essential to remove the buttermilk in order that the butter may keep and taste well, and the more completely this is effected the more successfully will that object be attained. As has been shown by experiments (particularly on a small scale) wherein the butter was carefully freed from the adherent buttermilk, such really pure butter is surprisingly stable, in so far as it is kept at a temperature not exceeding 15°-16° C., the pure fat being much less liable to decompose than that in contact with the buttermilk. In order to get rid of the latter the butter must be carefully washed with cold water, care being taken at the same time that the butter is in a condition as finely divided as possible, and that all the particles thereof come into contact with the continually renewed water employed.

Working the butter by hand is insufficient for large dairies, and therefore special machines have been made in which the butter is worked, either between grooved rollers or on a table, by a kneading roller, driven by hand or power. As a rule, eight or ten kneadings are sufficient to work out all the buttermilk, and all that then remains is to make the butter up into the form in which it is to be sold.

In winter time, and when the cows are fed largely on straw and sloppy fodder, the butter is very pale in colour, and attempts are made to remedy this by using butter colouring. At present general use is made for this purpose of arnatto (dissolved in hemp-seed oil or linseed oil), butter yellow or, in small dairies, even carrot juice, the butter being either mixed and kneaded up with the colouring or else the latter is added to the cream before churning, this last named plan resulting in a more uniform distribution of the colour.

The Bergedorfer cremometer (De Hardt's patent) is based on the separation of cream by centrifugal force. This apparatus is adapted for separator work, especially the Laval machine, and consists of: (1) a steel disc *a* (Fig. 46) to fit the separator, and containing (in a hollowed-out receptacle) a number of lateral borings for holding the test tubes; (2) forty-eight test tubes *b* with metal fittings together with a case for holding same; (3) a tin measure *c* for filling the tubes; (4) a needle *d* for regulating the amount of milk in the

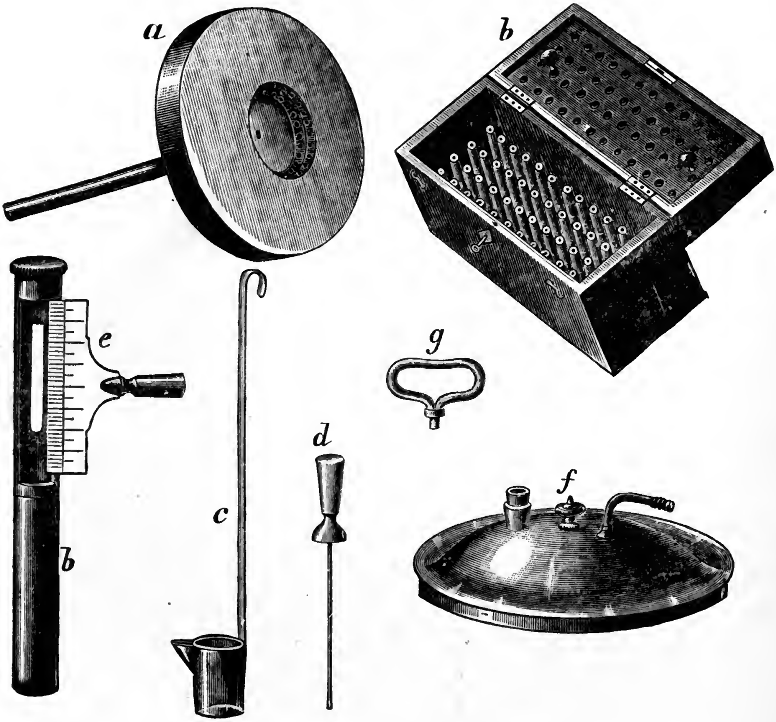

FIG. 46. Bergedorfer Cremometer.

tubes; (5) a scale *e* for reading off the percentage of cream; (6) a cover *f* with steam pipe for warming the disc *a*; (7) a handle *g* for lifting the disc out of the stand.

The apparatus is worked in the following manner: The milk to be tested is thoroughly mixed by agitation and pouring from one vessel to another, to ensure uniformity of sample, and is then, by means of the tin measure, poured into the metal receptacles forming the lower portion of the test tubes *b*. The tubes are then pressed into the receptacles, whereby the milk rises in the glass portion and the excess escapes through a small aperture at the top, through which aperture the needle *d* is inserted to adjust the quantity of milk in such a manner that none of the contents will afterwards escape as a result of expansion on heating.

The tubes are next placed in the borings in the disc *a*, which rests in the separator stand and has in the meantime been warmed up to 40° C. (maximum, 50° C.) by steam introduced by means of a rubber tube inserted through a corresponding hole in the lid, the cavity in the disc being also half filled with warm water for the same purpose. In fitting up the disc with the samples care must be taken to arrange the tubes symmetrically, in order that equilibrium may be maintained during the succeeding operation. Forty-eight samples may be treated at a time, the disc being kept in motion for twenty minutes at the ordinary speed of the separator, *viz.*, 6500 turns per minute. As soon as the disc comes to a standstill the test tubes are taken out and the height of the sharply defined column of cream ascertained by applying the graduated scale, the markings on which correspond to 1 per cent. of cream and are further subdivided to record $\frac{1}{5}$ and $\frac{1}{10}$ of 1 per cent., $\frac{1}{10}$ of 1 per cent. being easily read off after a little practice.

It is not absolutely essential to read off the percentage of cream at once, as this can be done with equal accuracy even some twenty-four hours later. The glass tubes are cleaned in a simple manner by filling the metal portion with warm water and pressing home the upper part, whereby the water is driven through the tube. The metal part and the bore holes are cleaned out by means of suitable brushes.

Properties.

The colour of butter varies considerably and ranges from a very pale to a fine deep yellow, winter butter being generally the palest, whilst summer butter is more highly coloured, this characteristic greatly depending on the composition of the fodder. The consistency is to an uncommon degree influenced by the prevalent atmospheric temperature, so that one and the same butter is fluid in summer and hard and solid in winter. Taste and odour should be agreeable and purely butter-like.

Specific Gravity at 16° C.: 0·936 to 0·943 (Hagen), 0·9275 (Winter-Blyth), 0·926 (Casamajor); at 37·8° C.: 0·911 to 0·913 (Bell); at 100° C. (water at 15° C. = 1): 0·865 to 0·868 (König); at 100° C. (water at 100° C. = 1): 0·901 to 0·904 (Wolkenhaar).

Melting-Point.—31° to 31·5° C.

Setting-Point.—19° to 20° C. (Wimmel).

Melting-Point of the Fatty Acids.—38° C.

Setting-Point of the Fatty Acids.—35·8° C. (Hübl), 37·5° to 38° C. (Paris Laboratory).

Hehner Number.—87·5.

Saponification Value.—227.

Reichert Number.—14·00.

Iodine Number.—26·0 to 35·1 (Hübl), 32·0 to 38·0; very old butter: 19·5 (Moore).

Unmelted unsalted butter contains under normal conditions, according to König:—

Fat	87·0 per cent.
Casein	0·6 ,,
Milk-sugar	0·5 ,,
Salts	0·3 ,,
Water	11·7 ,,

The composition, however, varies considerably, in that on the one hand the fat may amount to 95 per cent., whilst on the other the water may form as much as 35 per cent.

In consequence of its content of water and casein, butter quickly turns rancid. Attempts are often made to combat this rancidity by kneading the butter with 3 or 4 per cent. of common salt after thorough washing. According to Benedikt the same end may be better attained by keeping the butter in a melted condition until it has thoroughly clarified and then separating it from the precipitated water and casein. Milk fat treated in this way is, however, no longer saleable as butter, and also lacks the characteristic flavour of this article.

Apart from traces of colouring matter, lecithin, cholesterin, etc., pure butter fat consists solely of the tri-glycerides of the fatty acids. Up to the present, acetic acid, butyric acid, caproic acid, caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachic acid and oleic acid have been isolated therefrom. An unusually high percentage of glycerides of the volatile fatty acids is specially characteristic of butter, but the bulk is composed of stearine, palmitin (classed both together as margarine) and olein.

The composition of butter is :—

(*According to Schaedler*)

Margarine	66 per cent.
Olein	28 ,,
Butyrin	6 ,,

(*According to Winter-Blyth*)

Stearine and plamitin	50·0 per cent.
Olein	42·2 ,,
Butyrin	7·7 ,,
Caprin, caproylin	0·1 ,,

It may be calculated approximately as follows :—

When the Hehner number of a butter is found to be 87·5 and the average molecular weight of the insoluble fatty acids 270, then the sample contains 91·65 per cent. of glycerides of the non-volatile fatty acids—olein, palmitin and stearine.

If the iodine number be 30·1, it follows that the olein content is 35·96 per cent.; therefore such a butter—the glycerides of the volatile fatty acids being calculated by difference—contains :—

Margarine - - - - - -	55·69 per cent.
Olein - - - - - - -	35·96 ,,
Butyrin, caproin, etc. - - - -	8·35 ,,
	100·00 per cent.

An indication of the nature of the volatile fatty acids is afforded by the Reichert number. According to Meissl, the fatty acids distilled from 8 grms. of butter require, on an average, 28·48 c.c. of $\frac{1}{10}$-normal alkali for their saturation; consequently, the fatty acids from 100 grms. of butter require 57·56 c.c. of $\frac{1}{1}$-normal alkali. This corresponds to 0·729 parts of glycerine radicle $(C_3 H_2)$, which, deducted from 8·35, leaves 7·62 parts as the volatile fatty acids obtainable from 100 parts of butter. Therefore, 7·62 parts of volatile fatty acids require 57·56 c.c. of normal alkali for their saturation, and consequently their average molecular weight is about 139. The molecular weight of butyric acid is, however, 88, that of caproic acid is 116, of caprylic acid 144, and of capric acid 172. Consequently, Winter-Blyth's statement that butter fat contains 7·7 per cent. of butyrin and only 0·1 per cent. of glycerides of other volatile fatty acids requires correction, in that the percentage of caproin, caprylin and caprin is much higher.

As revealed by the microscope, fresh cow's butter consists of perfectly spherical transparent fat globules. Hassall found crystals in older butter, these being, according to Mylius, best detected when the fat is examined under the polariser with crossed Nicol prisms, the crystals alone being then illuminated, whilst the rest of the field is in darkness.

On prolonged exposure to the air, butter assumes the smell of tallow and becomes white. The setting of butter after melting does not progress uniformly, but a kind of crystallisation occurs. The portions nearest to the walls of the vessel are the first to crystallise, and they differ in composition from those remaining longer liquid in the interior of the mass. Sometimes this separation proceeds so far that an oil (" butter oil ") is obtained, which can also be isolated by allowing the melted butter to set at 20° C. and then subjecting it to pressure.

ADULTERATIONS OF BUTTER.

The additions made to butter are of a very divergent nature.

The coarser forms of adulteration consist of clay, chalk, gypsum, starch, meal, potato starch, ground white cheese, etc. Borax, water-glass and alum are sometimes added to preserve the butter and increase the weight by attracting the largest possible amount of water.

To impart a yellow coloration, small quantities of arnatto, saffron, curcuma, azo dyes, etc., are frequently added.

The most important adulteration, however, is that of added extraneous fats, such as hog fat, tallow, goose fat, cotton stearine, cocoa-nut fat and palm fat worked up with oil, and particularly oleomargarine. Though the addition of matters not belonging to the fat series can be easily determined both qualitatively and quantitatively, the detection of extraneous fatty matters in butter was long attended with great difficulty, until, finally, suitable methods therefor were elaborated by Köttstorfer, Hehner and Reichert. Of these, however, Reichert's alone still gives reliable results, since, according to Moore, mixtures can be prepared from oleomargarine and cocoa-nut oil to give exactly the same Hehner and Köttstorfer numbers as true butter. By means of the specific gravity determination and the Reichert number the purity of a butter fat can be decided satisfactorily in almost every case. Since, however, it is not impossible that the manufacturers of artificial butter may also succeed in preparing products with the correct Reichert number, it may be that other tests will have to be again resorted to in addition to Reichert's method. For this reason these, along with a few older methods of testing butter, are subjoined.

Beef Lard or Re-Melted Butter.

Butter, as is well known, easily turns rancid if not carefully kept, and such butter is, therefore, frequently converted by a careful re-melting into "beef lard" for culinary purposes. When butter is carefully melted by itself over a fire, a froth, mainly consisting of unremoved casein, collects on the surface of the liquid; but the solution of milk-sugar in water, present in the butter as a result of insufficient washing, is, however, not so easily removable, and remains in the butter. In practice it is generally considered sufficient to skim off the froth from the liquefied butter, so long as any forms, and to then fill the butter direct into wooden tubs, where it is left to set.

When the melting is carelessly performed and the temperature allowed to rise a little, this results directly in the development in the liquefied butter of an irritating, unpleasant taste, due to the formation of certain decomposition products. Therefore, as butter is an expensive product, it is advisable to proceed carefully in melting, so as to preserve the quality, the increased expenditure of labour being amply compensated by the improved results.

The best plan is to place the butter to be treated in a shallow vessel of thin, well-tinned sheet iron, this being set in another which is filled with water, and to which heat can be applied. Butter being, like all fats, a bad conductor of heat, melting would take a long time unless facilitated by stirring. So long as any of the butter remains unmelted, the water in the outer vessel may be kept on the boil, but as soon as the whole is liquefied the temperature is lowered until the butter is just fluid, and in this state it is left in repose for several hours without stirring.

Whilst in this condition of repose the particles of casein rise to the surface completely, and the aqueous liquid admixed with the butter subsides to the bottom, leaving the butter clear and transparent. Skimming is now practised, the most suitable method being to remove the uppermost layer by a skimming spoon and pour it on to a cloth of close texture spread out in a hair sieve, whereupon the fat runs away through the cloth, leaving behind the particles of casein. Only when the surface of the butter has been cleared of every particle of froth is the removal of the fat proceeded with, and is then continued until only about an inch deep of fat is left in the vessel, the residual portion being allowed to solidify, in which condition it can readily be separated from the underlying layer of water.

The product ("beef lard") thus obtained is a perfectly pure butter fat, without the slightest trace of rancid or empyreumatic flavour, and it is much better to prepare butter for cooking purposes in this way than to run the risk of its turning rancid.

A small sample of the "beef lard" taken from the setting vessel should be of a pure yellow colour and very translucent, a condition which can be attained by allowing the butter to cool only very slowly, *i.e.*, at a suitable and gradually decreasing temperature, so that the fat can crystallise uniformly. Usually the colour of the product is somewhat duller than that of the original butter.

TESTING BUTTER.

Benedikt prescribes the following methods for the testing of butter fat :—

Organoleptic Reaction.—Hager steeps a cotton wick in the fat, previously clarified by warming, and lights it for two minutes. In the case of pure butter a smell of burnt butter is perceptible but with oleomargarine the smell is that of acrolein.

Specific Gravity.—Bell determines the sp. gr. of the sample at 37·8° C. (= 100° F.), at which temperature the sp. gr. of butter is 0·911 to 0·913, and that of oleomargarine and other fats 0·9028 to 0·9046.

König performs the estimation at 100°C. and finds for pure butter 0·866 to 0·868, or for adulterated samples 0·859 to 0·865.

According to Adolf Mayer, who works with the ordinary areometer, at 100° C. (or, more correctly, at the temperature of boiling water), and thereby obtains figures of merely relative, not absolute, value, the state of the barometer must be taken into account, since a difference of 2 mm. in the barometer reading causes the sp. gr. to vary by 0·0001, so that the frequently occurring differences of 40 mm. of pressure will cause a discrepancy of 0·002, whilst the total difference in sp. gr. between natural and artificial butters amounts to only 0·007.

Casamajor employs the Hager method. The fat is melted in a spoon and one drop is introduced into 56·5 per cent. alcohol, the sp. gr. of which is exactly midway between butter (0·926 corresponding to 53·7 per cent. alcohol) and oleomargarine (0·915 = 59·2 per cent. alcohol) at 15° C. Should an air bubble adhere to the drop of fat it is detached by the aid of blotting paper. If the drop does not sink a slight concussion will cause it to do so if heavier than the liquid. Butter sinks to the bottom, whilst oleomargarine floats. If a drop of the melted sample be poured on to the spirit, warmed to 30° C., it will set, if butter, whereas oleomargarine remains liquid, although both float. On reducing the temperature to 15° C. the latter fat solidifies as well, and butter sinks. A " butter " that will not sink in 55 per cent. alcohol is oleomargarine with at most a third of cow's butter.

According to Moore, adulteration of butter by a mixture of oleomargarine and cocoa-nut oil cannot be detected by this means, since the sp. gr. of the cocoa-nut oil (0·9167 at 37·7° C.) is high enough to raise the sp. gr. of the mixture to that of butter (0·911 at 37·7° C.).

Emulsifiability.—According to Adolf Mayer, butter exhibits a greater capacity for forming emulsions than any of the fats employed to adulterate it, because the latter have been melted in the purifying process. He therefore sought to establish on this basis a simple method of testing, which, however, cannot be regarded as perfectly reliable.

Solubility.—The following tests for butter are based on the different solubilities of butter and its adulterant fats :—

Hoorn dissolves 1 grm. of the sample in 7 c.c. of petroleum spirit and leaves the solution to stand a few hours in tightly closed vessels at 10° to 15° C. Butter fat remains dissolved, whilst veal fat, tallow and hog's lard separate out.

Münzel dissolves 1 grm. of the fat in 12·5 grms. of absolute alcohol (sp. gr., 0·797) on the water bath, closing the tube with a cork pierced to allow the passage of a thermometer, which reaches down to the bottom of the tube. The latter is then removed from the water bath, dried rapidly and the temperature at which the fat begins to set noted. Münzel obtained the following results :—

Commencement of Solidification.

Pure Butter	34° C.
,, + 10 per cent. of horse fat	37° ,,
,, ,, 20 ,, ,, ,, ,,	40° ,,
,, ,, 30 ,, ,, ,, ,,	44° ,,
,, ,, 10 ,, ,, tallow	40° ,,
,, ,, 20 ,, ,, ,,	43° ,,
,, ,, 30 ,, ,, ,,	46° ,,
,, ,, 10 ,, ,, hog lard	38° ,,
,, ,, 20 ,, ,, ,,	41° ,,
,, ,, 30 ,, ,, ,,	43° ,,
Margarine butter	56° ,,
Butter + 25 per cent. of oleomargarine	40° ,,
,, ,, 50 ,, ,, ,,	48° ,,

Horsley, Balland, Husson and Filsinger have made use of the varying solubility of pure and adulterated butter in ether or ethyl alcohol as a test of purity. Crook employed carbolic acid as solvent, and his results were confirmed by Lenz, with only a slight divergence in the values. Ten grains (0·648 grm.) of the filtered fat are dissolved in a gauged testing cylinder at about 66° C., shaken up with 1·5 c.c. of liquid carbolic acid (containing 373 grms. of crystallised carbolic acid and 56·7 grms. of water) and warmed on the water bath until transparent. After standing a while at ordinary temperature, one has either a clear solution (butter) or two strata separated by a clear line of demarcation (beef, mutton, hog fat). The volume of the lower stratum amounts to :—

	Crook.	Lenz.
Beef fat	49·7 per cent.	— per cent.
Mutton fat	44·0 ,,	39·1 ,,
Hog fat	49·6 ,,	37·0 ,,

After sufficient cooling, more or less deposit is apparent in the upper layer. With 5 per cent. of hog fat Lenz could no longer detect any separation into two layers, but at the end of twenty-four hours a crystalline turbidity, differing from that observed in true butter, made its appearance.

More recently Zeiss' butyro-refractometer has been largely used for butter testing, adulterations being rapidly detectable therewith. This instrument, supplied by C. Zeiss of Jena, is shown in Fig. 47. A and B are the hot-water jackets surrounding the two prisms and facilitating the testing of the fats at temperatures above their melting-points. C is a hinge on which B turns, D the water feed pipe and E the outflow pipe. The bayonet catch for the hot-water jacket is at F, and G is a pin serving to adjust the object ; H serves as a support for A and B, and J is the reflector.

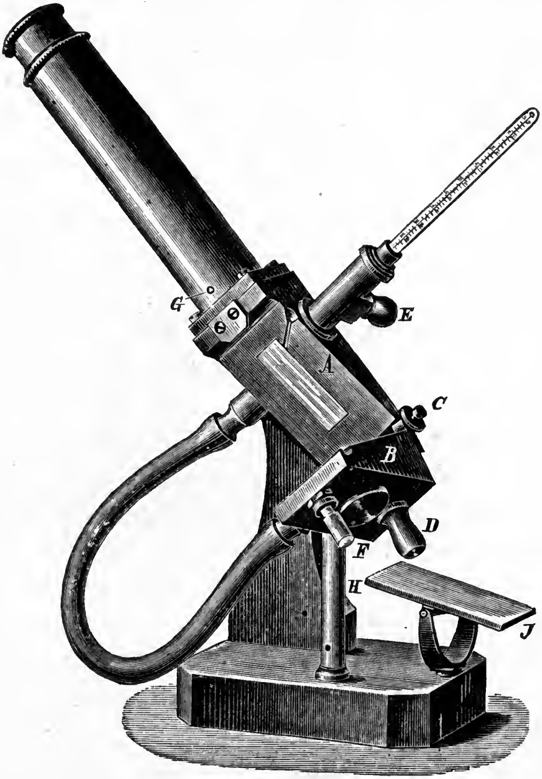

FIG. 47. Zeiss' Butyro-Refractometer.

This instrument is based on the principle that the refractive powers of the fatty acids afford a means of determining their purity. It consists chiefly of a pair of prisms enclosed in a jacketed metal case, which, by the aid of a current of water, enables the substance enclosed between the two prisms to be kept at a constant—higher or lower—temperature. Above the prisms is mounted a telescope with a scale, on which the position of the critical line of the substance between the prism can be read off direct. According to the position and colour of the critical line—red in pure butter, otherwise blue—it can at once be determined, by the aid of the reduction tables supplied with the instrument, whether the butter is natural or artificial. With a little practice, twenty to thirty examinations can be made in the hour.

Woollny obtained the following values for natural butter, margarine and mixed butter, expressed in degrees of the scale at 25° C. :—

Natural butter - - - - -	49·5-54·0 degrees.
Margarine - - - - - -	58·5-66·0 ,,
Mixed butter - - - - -	54·0-64·8 ,,

Butter with a refractometer index of 54·0 is always an object of suspicion, and should be subjected to further examination.

The complete analysis of butter is performed as follows :—

1. *Estimation of Water.*—Five to ten grms. of butter are weighed out into a covered beaker and melted in the air oven. When the fat is clear it is filtered (still in the oven) through a tared filter into a tared flask, care being taken to pour through the filter as much of the fat and as little of the underlying water as possible. The aqueous residue is then evaporated in the beaker at 100° C., and the whole of the remaining substance is placed in the desiccator and weighed, dried, cooled and re-weighed until the weight is constant or varies by not more than 1 m.grm. The loss in weight sustained by the fat—the weight of the beaker being known at the outset—gives the amount of water therein.

2. *Estimation of Fat.*—The residue in the beaker is loosened as well as possible from the bottom by means of a glass rod and washed with water-free ether on to the filter, which has been placed in a funnel in the mouth of the flask holding the bulk of the fat, the beaker and rod being rinsed and the filter and contents washed with ether until a test drop on a watch glass shows that all the fat is removed. The ether is then distilled off and the fat dried in the air oven at 100° C., cooled in a desiccator and weighed when cold, the operations being continued until the weight is constant.

3. *Determination of Ash.*—The residue collected on the filter and the filter itself are carbonised in a platinum curcible at a moderate heat and, after extracting several times with distilled water and filtering, calcined thoroughly. The filtrate is then poured by degrees into the ash in the cooled crucible and the whole dried in the water bath, incinerated with the used filter in the (covered) crucible, cooled and weighed, the weight of the two filters being deducted from the result. In the case of salted butter, only the total amount of the mineral salts can be given, the exact estimation of the sodium chloride being impossible in the presence of the other ash constituents also containing chlorides. As, however, butter generally contains no more than 0·10 per cent. of ash, the percentage of chlorine can only be very small, and the amount of salt used can therefore be very approximately determined from the chlorine in the ash.

4. *Estimation of Protein.*—Eighty to 100 grms. of butter are weighed out and the fat separated completely—after evaporating the water—from the other constituents in the manner already described in the estimation of moisture and fat, the residue, carefully collected on the filter, being used for the determination of nitrogen; the result multiplied by 7·042 gives the percentage of protein. Bearing in mind,

however, that it is doubtful, especially in the case of old butter and that from sour cream, whether all the nitrogenous bodies belong to the albuminoid group, a little uncertainty probably attaches to the figures given for protein.

5. *Estimation of the Soluble Non-Nitrogenous Matter* (milk-sugar, lactic acid, etc.).—The percentage content of water, fat, ash constituents and protein having been precisely determined by two satisfactory and concordant analyses, then the figures thus obtained are added together and the total deducted from 100, the remainder being regarded as expressing the percentage of non-nitrogenous organic matter. According to observations made in the Kaaden Laboratory, attempts to estimate this group direct do not generally attain the desired object, since in the washing of the fat-free residue more or less of the nitrogenous matter passes into solution. The figures ascertained for non-nitrogenous organic matter by difference are also affected by the uncertainty attendant on those for protein.

As it is desirable, for the purpose of judging the purity of a butter, to know the chemical composition of the butter ash, the complete ash analysis of unsalted, unwashed, well-worked butter is now given; the ash amounted to 0·1485 per cent.:—

Crude Ash.		
Moisture	0·600	per cent.
CO_2	0·233	,,
Carbon	0·333	,,
Silica and sand	0·533	,,
K_2O	19·000	,,
Na_2O	7·583	,,
CaO	22·700	,,
MgO	3·232	,,
P_2O_5	43·520	,,
Cl	2·560	,,
Iron, H_2SO_4 and loss	0·283	,,
	100·577	per cent.
From which must be deducted oxygen	0·577	
	100·000	per cent.

Purified Ash.

K_2O	19·329	per cent.
Na_2O	7·214	,,
CaO	23·092	,,
MgO	3·287	,,
P_2O_5	44·273	,,
Cl	2·604	,,
Iron, H_2SO_4 and loss	0·288	,,
	100·087	per cent.
Deduct oxygen	0·087	
	100·00	per cent.

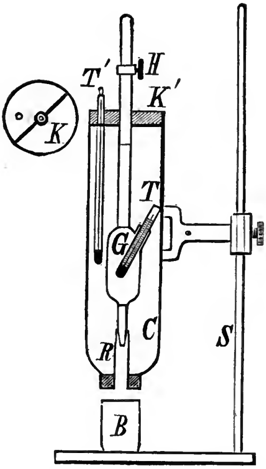

Fig. 48. Killing's Viscosimeter.

For distinguishing between butter and margarine, and also for estimating the content of extraneous fats existing in butters, Dr. Killing employs the viscosity test. Since the ordinary types of viscosimeter are unsuitable for this purpose, by reason of their insufficient accuracy and by requiring excessive quantities of fat, he constructed a special viscosimeter wherein these defects were obviated. In this apparatus (Fig. 48) eleven samples of margarine of various origin and price gave viscosities (the duration of outflow of water at 20° C. = 100) ranging between 313·3 and 317·4, whereas in eight natural butters the viscosity varied from 276·2 to 281·3. The author considers these investigations by no means final, the principles underlying the method having still to be determined by experience. In any case, the method appears advantageous, in that no chemical knowledge is required for its performance.

The apparatus used by Killing is constructed as follows :—

The lower opening of the glass cylinder C is closed by a perforated caoutchouc stopper traversed by a tube R which supports a pipette-like vessel G (holding about 50 c.c.) closed above by a tap H and tapering off below to an aperture about 1 mm. in diameter. The body of G contains a thermometer T, ground to fit the tubulus. Marks are inscribed on the pipette close below and above the bulb, and a third about 10 cm. above the upper one. G and R are fitted by grinding. The cylinder is closed at the top by two semicircular corks K, one of which carries a thermometer T^1, and the entire apparatus is supported over a beaker B by the clamps of the stand S.

To standardise the apparatus the two thermometers T and T^1 are immersed in a beaker of water and compared with a normal thermometer at 20° and 40° C., at which latter temperature the examination of the butter is performed. Therefore, if the thermometer T registers 39·5° C. when the normal instrument records 40° C., the test must be carried out at the former temperature as indicated by T. The same applies to T^1, and is essential in order that the results, which depend greatly on the temperature, may be concordant when obtained by different observers.

To set the apparatus in working order the two semicircular corks K with the thermometer T^1 are removed, the vessel G taken out and the thermometer T withdrawn. The butter is melted at 50°-60° C. in a drying oven and separated from the non-fat by filtration, some 60 c.c. (sufficient for the test) of the clarified fat being kept in readiness in the oven. On the other hand, about 1½ litres of water are warmed up to 43° C. in an enamelled iron saucepan fitted with a lip for pouring, the thermometer T^1 being used for stirring the liquid. As soon as the prescribed temperature is attained the flame is extinguished, and the butter then cooled (by dipping the beaker in cold water and continually stirring with the thermometer T) from its temperature of 50°-60° C. down to 40·5° C. When this moment has arrived T is placed in position without any further cleaning and the butter drawn up in G by suction to the upper mark, the greased tap shut and G placed upon R, whilst the beaker containing the rest of the butter is placed under the apparatus. The water, cooled in the interim down to 42° C., is next poured as quickly as possible into the cylinder C, leaving just enough room for the insertion of the semi-cylindrical corks, one of which always remains attached to the thermometer T^1, even whilst the latter is being used to stir the water in the saucepan. When these operations have been carefully performed both thermometers will in a very short time register 40° C., whereupon, by gradually opening the tap, the oil is allowed to run out until the upper level corresponds with the mark over the bulb, and the tap is then fully opened by a quick movement of the one hand, whilst the other sets the chronoscope in motion, the latter being stopped when the oil has run off to the level of the lower mark.

With a little practice, the times observed with one and the same material will agree to within a second, the variations mostly amounting to a ¼ to ½ a second. By stating the time of outflow of water at 20° C. as equal to 100 and referring to this the time taken by the butter or margarine fat, the viscosity number is derived.

According to Dr. C. Aschmann, 5 grms. of the fat should, for the differentiation of natural and artificial butters, be treated by the usual Reichert-Meissl method for the liberation of the fatty acids and the latter dissolved in 60 c.c. of ether, 20 c.c. of the solution being then placed in a 100 c.c. glass tube (about 40 cm. long) along with 8 c.c. of normal potash and 30 c.c. of a solution of common salt (sp. gr., 1·075), and the whole well shaken up. At the end of one or two hours the ether will have collected above the brine, but will not be clear, being rendered turbid by precipitated matter, the height of which will, in the case of natural butter, measure only 20 to 30 mm., but for margarine will amount to at least 60-70 mm., and will, with a little practice, afford an accurate differentiation.

Uses of Butter.—For alimental purposes.

Candle-Fish Oil (Gulachonöl).

Raw Material.—The candle fish ("Gulachon" or "Ontachon"), found in enormous shoals in the bays on the coast of British North America and Alaska. This fish, which is also highly prized as a food, is so rich in oil that it is used in the dried state for torches: hence its name.

Preparation.—No information is available on this point, but probably by pressing like all other fish oils.

Properties.—Schaedler reports on this new and interesting product as follows:—

The oil as it is put on the market contains a deal of palmitin and probably stearine, so that it is only semi-fluid at the ordinary temperature. The olein, for so this product must, for medicinal purposes, be regarded, forms a clear, pale, straw-yellow liquid of fishy smell, differing from, and to many tastes probably less repugnant than, liver oil. The sp. gr. is 0·9071 at 15° C. and 0·9012 at 25° C., whilst that of liver oil varies between 0·92 and 0·93, but is generally 0·9227 at 15° C. When mixed with sulphuric acid

(1 vol. of acid to 5 parts of oil) the temperature rises 55° C., whereas liver oil under the same conditions undergoes a rise of 112° C. The colour reactions also differ from those of liver oil, nitric acid (sp. gr., 1·27), mixed with one-third of its volume of the oil, producing at once a rose coloration gradually changing to amber yellow.

At the end of fifteen hours the mixture will have thickened considerably and assumed a deep amber coloration. Liver oil treated in the same manner turned rose-red at first, then rapidly into amber, and exhibited the same coloration in fifteen hours' time, but was more fluid than the first-named mixture and interspersed with thicker layers. Sulphuric acid gives with candle-fish oil not the same beautiful purple colour that it does with liver oil, but a deep brown, subsequently inclining to both yellow and red. When this oil is saponified the precipitated fatty acids amount to 95·85 per cent. of the oil.

Candle-fish oil contains about 20 per cent. of palmitic and stearic acids, 60 per cent. of olein and 13 per cent. of an unsaponifiable substance, which, being a peculiar and interesting body, deserves careful examination. At summer temperature this substance forms a mass of oily consistency, has a sp. gr.—0·865 to 0·872 at 15° C.—inferior to that of any other constituent of ordinary fats, and appears to be similar to the unsaponifiable matter in sperm oil.

MUTTON TALLOW (HAMMELTALG).

Raw Material.—The accumulations of fat in the flesh and tissues of the sheep.

Préparation.—Like beef tallow, by melting and by pressing the residual tissues from the melting process.

Properties.—Mutton tallow is similar to that of the ox, but less highly coloured, being white and rather hard and brittle. Initially inodorous, it assumes, after a brief exposure to the air, the well-known characteristic smell and taste of mutton, very quickly becomes rancid and agrees in this property with goat's fat, which it then resembles in smell. These odours are due, according to Chevreuil, to a volatile fatty acid (hircinic acid), which is, however, merely a mixture of butyric acid with other volatile fatty acids.

Specific Gravity at 15° C.—0·937 to 0·940 (Hagen), 0·961 (Dieterich); at 100° C., 0·860 (König).

Melting-Point.—46·5° to 47·4° C., 46° C. (Schaedler).

Setting-Point.—32° to 36° C., rising thereupon to 40°-41° C. Old mutton tallow melts at 49°-50° C., sets at 39°-40° C. and rises thereupon to 44°-45° C. After setting, the fat exhibits a flat surface and, internally, traces of crystalline structure.

Setting-Point of the Fatty Acids.—45°-46° C.; also 43·2° C. (Dalican), 46·1° C. (Schepper and Seitel). Mutton tallow is soluble only in over 60 volumes of cold ether or 45 volumes of boiling alcohol of sp. gr. 0·821.

It contains per 100 parts :—

Carbon	76·61 per cent.
Hydrogen	12·03 ,,
Oxygen	11·36 ,,
	100·00 per cent.

and consists of about 70 per cent. of stearine and palmitin (margarine) and 30 per cent. of olein.

The olein obtained by pressure is colourless, with a faint odour of mutton and a sp. gr. of 0·913 at 15° C.; 80 parts are dissolved by 100 parts of boiling absolute alcohol. On account of the crystalline appearance of the stearine yielded by this fat, mutton tallow is preferred by candle makers to that of the ox; very frequently the two are met with melted together.

Uses.—Similar to those of beef tallow.

HARE FAT (HASENFETT).

Hare fat is white, or occasionally somewhat yellowish, with characteristic smell and a mild, agreeable taste ; the consistency is rather softer than that of lard.

Specific Gravity at 100° C.—0·861 (König).

Melting-Point.—44°-46° C.

Setting-Point.—28°-30° C.

Co-efficient of Refraction (Zeiss) at 40° C.—49.

Percentage of Solid Insoluble Fatty Acids.—95·47 per cent.

Volatile Soluble Fatty Acids (Reichert-Meissl number) = 2·64 c.c. of $\frac{N}{10}$ – NaHO per 5 grms.

Insoluble fatty acids :—

Melting-Point.—48°-50° C. ; *setting-point*, 39°-41° C. ; *co-efficient of refraction*, 36.

GOOSE FAT (GÄNSEFETT).

Raw Material.—The accumulations of fat interspersed among the tissues and under the skin of the goose.

Preparation.—By carefully melting the cut-up fat and straining to separate the product from the cellular tissue.

Properties.—It is white to pale yellow in colour, translucent, granular, frequently almost liquid at 10° to 12° C., of agreeable flavour and does not easily turn rancid.

Melting-Point.—25°-26° C.

Setting-Point.—18° C., the temperature then rising to 22° C. (Schaedler).

Saponification Value.—192·6 (Schaedler).

Iodine Number.—71·5 (Erban and Spitzer).

Uses.—For alimental purposes.

NEATSFOOT OIL (KLAUENÖL).

Raw Material.—The hoofs of cloven-footed animals, oxen, sheep and goats.

Preparation.—The feet of the ox and the sheep contain a very liquid and stable fat. In order to obtain this substance the fresh feet are laid in cold water to wash away the adherent blood and, after the sinews have been removed, are then placed in sufficient boiling water to cover them. After immersion for a quarter of an hour therein they are taken out, the claws cut away and the feet split to separate the toes from the larger bones, the latter being then boiled in water by the aid of steam, whilst the former, which yield up their fat less readily, are placed in a pan and boiled over direct fire in the water that has already served for boiling the large bones. After a prolonged boiling the liquid is allowed to clarify, whereupon the fat rises to the surface and is poured off. The oil obtained in this manner deposits after some time a dirty semi-fluid fat, from which the liquid portion is separated by decantation. This oil is pale yellow in colour and thin at ordinary temperatures, setting only at a few degrees below zero C. It contains much oleic acid and only a little stearine, does not easily turn rancid nor does it readily thicken. After the fat still remaining in solution has been as far as possible separated by crystallisation and filtration, the liquid product forms a very good lubricating oil for clocks and delicate machinery.

According to Th. Chateau, the preparation of neatsfoot oil is carried out in the following manner: The feet ("trotters") of about 100 sheep are treated for twenty minutes in a pan of water warmed by the aid of steam up to 75° or 80° C. When the woolly hair comes away easily the pan is emptied, the feet scraped and the claws removed. The feet thus cleaned are tied up with string into bundles of eighteen and then subjected to extraction by boiling in water until the greater part of the contained oil is recovered, whilst the feet themselves are sold in the half-cooked state. From 100 to 125 bundles of eighteen are treated at a time. The yield of fat is somewhat variable, ranging from 1 lb. to 21 lbs. per 100 sheep. The feet of animals that have had to traverse long distances before being slaughtered, such as is the case with American sheep, yield merely traces of neatsfoot oil. The boiled feet are immediately laid in a stream of cold water, and when cooled are offered for sale. The oil obtained in this manner has a sp. gr. of 0·915, is translucent and grey in appearance, but clarifies on standing or by several filtrations, and is then very pale yellow in colour. Chateau, in his communication, reports that the majority of commercial neatsfoot oils examined by him were composed of other fats.

E. Geissler points out that neatsfoot oil is, on account of the method of preparation, very often rancid, and that he has examined oils of this class containing 10 to 15 per cent. of free fatty acids.

According to Schaedler, true neatsfoot oil from the hoofs of oxen is mostly mixed with that from the feet of the sheep.

Benedikt distinguishes between ox neatsfoot oil, sheep's-foot oil and horse-foot oil, and states that commercial neatsfoot oil is generally a mixture of oils from the hoofs of oxen, sheep, horses and swine. Data for the accurate differentiation of these oils are still entirely lacking.

Properties.—Neatsfoot oils are straw yellow, inodorous, of agreeable flavour and generally set only below 0° C.

Specific Gravity at 15° C.—Neatsfoot oil, 0·914-0·916 (Allen); sheep's-foot oil, 0·9175; horse-foot oil, 0·913 (Schaedler); at 18° C., neatsfoot oil, 0·9142 (Stilurell).

Adulterations.—Purified neatsfoot oil is in good demand as a lubricant, and is falsified with refined cotton-seed oil, rape oil and mineral oils, the detection of which is not difficult. Any admixture of pale fish oils can be recognised by the smell evolved when rubbed on the hands; otherwise by phosphoric acid.

Uses.—Technical, as a lubricant for delicate machinery, clocks and so forth.

BONE FAT (KNOCHENFETT).

Raw Material.—Large hollow bones and short flat bones, or rather the spongy substance of the latter. Bones are filled with a soft yellow or reddish fat (bone marrow) which serves to protect and support the blood vessels in the bone and also as formative substance for the white corpuscles of the blood. The bones worked up for their fat are those of the domesticated animals slaughtered for food and of the horse. As a rule, three products are obtained in the process: glue, fat and mineral matter, *i.e.*, phosphate of lime, the latter in the form of purified bone or as a manurial substance, or boneblack.

Preparation.—Originally the treatment of bones was confined to the extraction of the fat, the material being simply boiled in water and the fat skimmed off; probably also the glue, so far as the latter was dissolved by the boiling water, was recovered, the residual bones being worked up by the turner or bone worker, or ground down into bone meal.

The methods of manipulating bones employed at the present time may be directed to the attainment of four different objects:—

1. The recovery of fat and boneblack as the primary object, with bone meal as a secondary consideration;
2. Fat and boneblack as the main products; glue and bone meal, bye-products;
3. Fat, glue and bone manure or phosphate as the principal products;
4. The recovery of ammonia salts in addition to the products named under 1 and 2.

In any case, whatever products are to be obtained, the separation of the fat is necessarily the first task to be performed. Even in the event that bone meal is the sole manufacturing product in view, the recovery of the fat is unconditionally desirable on account of its relatively high value, and the bones are of no greater value for manure with the fat left in than without it.[1]

The form in which the bones should be used for recovering the fat, the sole object at present in view, is always that of small lumps, such as are obtained by passing the bones through crushing rollers set closely together. In working with bones crushed by stamping, the meal and granules with which the unsorted lumps remain mixed unfavourably affect the progress of the operation, whether boiling or extraction, by clogging together and rendering the recovery of the fat more difficult.

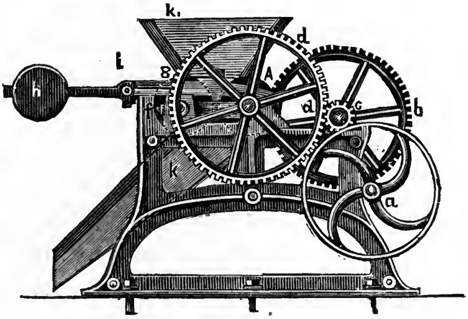

FIG. 49*a*. Bone Crusher. (Section.)

Properly crushed bones contain no meal and but few granules, and are in this form best adapted for yielding up their content of fat.

The recovery of fat may be effected in three ways :—

1. By boiling,
2. By steaming,
3. By extraction.

By simple boiling the bone cartilage is left almost entirely unaltered, the fat, however, being so imperfectly extracted

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[1] *Translator's Note.*—In fact they are the better for its removal, the fatty matter impregnating the bones retarding indefinitely their decomposition in the soil.

by this operation that frequently only one half the quantity actually in the bones is recovered.

By steaming the bones a much greater yield of fat is obtained, it is true—over 90 per cent. being recovered by sufficiently prolonging the operation—but, at the same time, a large portion of the cartilage is dissolved and converted into glue, which, if the manufacture of this article does not fall within the scope of the factory, is completely wasted, and even forms a burdensome waste product, in that the glue liquor, unless quickly discharged into a large volume of running water (river), very rapidly undergoes decomposition and infects the neighbourhood. The easiest method of getting rid of this glue liquor is by employing it for the irrigation of the land. Bone meal obtained from steamed bones is more easily dissociated than that prepared from unsteamed bones, on which account it has a more rapid fertilising action than the latter and is therefore, for this reason, usually considered by practical men as superior, though this is in reality not the case; and, moreover, such bones when converted into boneblack are of lower value, owing to the extraction of the gelatine, and yield a black of inferior decolorising power.

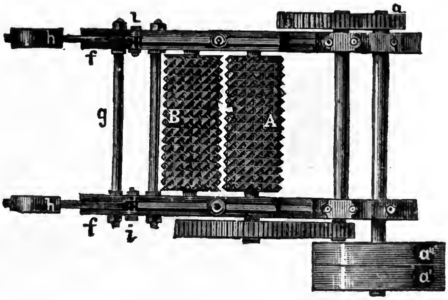


FIG. 49*b*. Bone Crusher. (Viewed from above.)

By the extraction process the fat is almost entirely obtained in solution, only a few parts per mil. at most being left behind in the bone. The cartilage, as well as the mineral matter, remains completely unaffected, and bones deprived of their fat in this manner may be used either for the preparation of a good bone meal which will have an abiding manurial effect or for the manufacture of boneblack. The extraction method is already undoubtedly recognised as producing the best results of any.

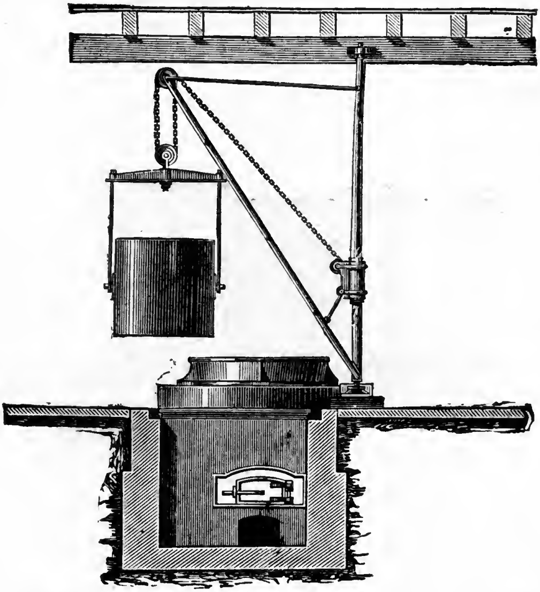


FIG. 50. Bone-Boiling Pan with Lifting Gear and Perforated Vessel.

1. *Bone Boiling.*

The oldest form of apparatus employed for bone boiling consisted of a large sheet-iron boiler set in brickwork and heated by direct fire. The pan was first filled with bones up to about 12 to 15 in. from the brim and water run in until the level of the liquid was about 8 in. below the edge, heat being then applied and continued until a fatty layer collected at the surface, this being skimmed off by flat ladles as fast as formed and collected in a wooden vat, where it was left to set. Under the fatty stratum there was always found a certain quantity of dark-coloured glue liquor, which was poured off. As soon as only a scanty amount of fat was found to be coming up to the surface of the water the operation was considered at an end, the glue liquor was run off and the bones taken out of the pan, to be then dried and subsequently worked up.

A slight improvement on this original practice of obtaining fat from bones consisted in placing the latter in a tin cylinder (Fig. 51) perforated like a sieve in the lateral walls and suspended by a strong bow from a chain running over a pulley attached to a revolving crane, by the aid of which it could be lowered into the boiling pan.

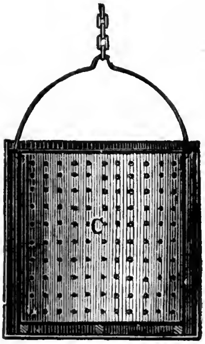


FIG. 51. Perforated Vessel for Holding the Bones.

In this latter vessel the cylinder was allowed to remain until no further notable quantity of fat could be skimmed off the surface of the water, whereupon the cylinder was lifted out and replaced at once by another full of fresh bones, which were boiled in the same water, whereby a glue liquor was obtained of sufficient strength to pay for working up into glue.

With regard, however, to the suitability of the same water for continuous use with fresh charges of bones, a difficulty soon arises, in that the density of the liquor becomes so great that the ascent of the fat globules is hindered and they remain imprisoned in the liquor, water having to be added as a diluent to enable the fat to separate.

Where steam is available, the boiling is effected by direct steam, which presents the advantage that large wooden vats may be used and the consumption of heat is relatively low. Direct steam may also be employed in the following manner: the aforesaid perforated vessel is immersed in a wooden vat full of water, at the bottom of which is placed a coiled steam pipe, the steam from which heats the water to boiling.

2. *Steaming Bones.*

The temperature of steam increases according to the pressure to which it is subjected, and it also forces its way more readily into the substance of bodies than when in the liquid state (water). These two factors, conjoined with the circumstance that strongly heated fat is very fluid, cause bones that are subjected to the influence of fairly high-pressure steam to yield a far larger quantity of fat than can be obtained therefrom by simple boiling.

Heated steam has, moreover, much greater solvent powers than hot water, and exerts this influence in the case of bones by converting a comparatively large amount of the cartilage into glue, so that in addition to obtaining a greater yield of fat from the bones by steaming, a more highly concentrated glue liquor is also produced than by mere boiling; the steamed bones themselves, being rendered more friable by the solution of an appreciable proportion of their cartilaginous substance, are softened and can be more easily comminuted. The apparatus generally used—with slight modifications—for steaming bones takes the form displayed in Fig. 52. It consists of a cylinder 10 or 12 ft. in height and composed, like an ordinary boiler, of strong iron plates. In each of these cylinders, which are set up vertically and arranged in groups or "batteries," are two large apertures, E and A, which can be shut steam-tight by iron covers and bow-screws. In the upper convexity of the cylinder is fitted a pipe D communicating with the boiler, and on the opposite side of the top is a short pipe H, both this and D being provided with taps. At the bottom of the cylinder is a pipe L, also fitted with a tap and bent forwards, and the cylinder is fitted internally with a perforated false bottom S immediately over the domed bottom. Generally four to six, or in large works eight and more, steamers are united to form a battery, the discharge pipes L being led into a common outlet, whilst the

FIG. 52. Bone Steamer.

steam pipes D are supplied from a main feed pipe. The batteries may be surrounded by brickwork, but it is preferable to mount them unenclosed and merely lagged with wood on a frame, the intermediate space between the boards and the steamer being packed with sawdust.

For filling the steamers quickly and with the smallest expenditure of power, it is advisable to set the crushing mill at such a height that the crushed bones fall direct into trucks which run on rails above the upper manholes of the steamers and are unloaded there by tipping. Another set of rails runs along in front of the second manholes A, so that the spent bones can be discharged direct into trucks and transported therein to the breakers.

As soon as a steamer is charged with bones it is hermetically closed, the tap H is opened and steam admitted to the bones by opening D. The steam first entering is condensed to water, being cooled by the bones, but after a short time the temperature in the steamer will have so far risen that the steam no longer liquefies, but after driving the air in the apparatus out through the pipe H issues therefrom itself in a strong current. As soon as this is observed H is closed and the steam allowed to act on the bones, whereby the fat therein is melted and trickles down. At the bottom of the vessel there collects a liquid containing glue, and rendered turbid by imprisoned fat globules, a thick layer of fat surmounting the whole. From time to time, at intervals of about an hour, the tap L is opened a little way, the pressure of the steam expels the glue liquor and fat with great force, and the tap is only closed again when the characteristic sound indicates that steam alone is escaping.

Steaming, with periodical removal of the fat, is continued until a sample of the effluent liquid shows that no more fat is coming away. The liquid in the steamer is then expelled by the steam, the steam pipe D closed and the outlet A opened, whereupon the steam is turned on again and forces the greater part of the charge of bones out through A, an operation greatly facilitated when the perforated false bottom S is arranged to slope well forward. The liquids obtained from the steamer consist of melted fat and a fairly concentrated solution of glue retaining a large proportion of fat. To separate these constituents the liquor is run into a steam jacketed metal cylinder, the current of steam being regulated to produce sufficient warmth to keep the glue liquor rather fluid, so that, on standing, all the contained globules of fat are enabled to rise to the surface. When the separation is complete the fat is run off through a tap at the side of the cylinder and the glue liquor immediately drawn off through a valve in the conical bottom of the vessel to the concentrating pans. The glue liquor being always fairly rich, it is advisable to work it up into glue in the factory, since, even if the resulting product be merely of low quality, the loss of valuable material sustained by the bone meal or boneblack is to some extent compensated thereby. It is somewhat difficult, in the type of steamer described, to warm the mass quite uniformly; consequently the melting of the fat takes a rather long time, so that a large amount of cartilaginous substance is converted into glue.

This may be remedied by an improved method of construction, wherein the steam pipe does not debouch into the top of the steamer but is modified in order to secure the better distribution of the steam through the charge of bones. The steam pipe (Fig. 53) is extended to the centre of the steamer and then passes downward in the direction of the axis almost to the bottom. A number of lateral apertures *o* are provided at various heights in the pipe, each of them being so protected by a small bent metal plate *d* that no solid bodies can pass into the tube, whilst, at the same time, the free discharge of steam is ensured. These protectors were found necessary to prevent the obstruction of the pipe, otherwise liable to occur, from small pieces of bone.

The *modus operandi* of this arrangement is easy of explanation: The steam passes through the numerous apertures in the pipe and uniformly heats the bones in many places at once, the temperature consequently rising quickly to a point at which the fat melts out.

The entire aim of the process—recovery of the total amount of extractive fat in a short time and the consequent restriction to a minimum of the conversion of cartilage into glue—is attained by this very simple arrangement. Finally, by adhering to this construction the diameter of the steaming cylinders can be increased and the bones still heated uniformly.

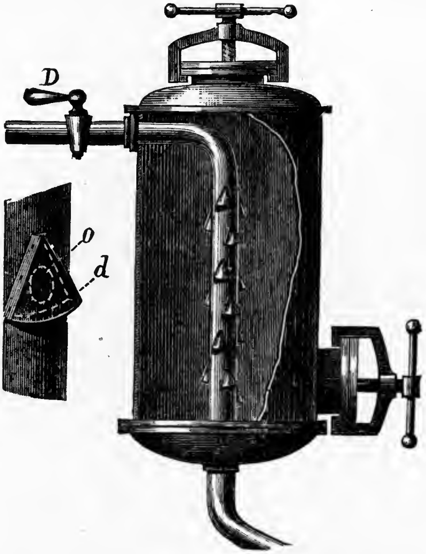


Fig. 53. Friedberg's Improved Bone Steamer.

3. *Extraction.*

The extraction process is, as already stated, the only one by which it is feasible to obtain from bones the contained fat in its entirety and at the same time preserve the cartilaginous substance perfectly intact, so that the best quality of boneblack may be prepared from the residue. Hence there is no need to undertake the manufacture of glue in order to make good the loss of matter—a consideration of great value in simplifying the work of the establishment.

The recovery of fat from bones by this process is based on the property of certain liquids, such as ether, carbon bisulphide, petroleum, benzol, etc., of extracting fat in the warm, bringing it into solution and then yielding it up again on simple distillation. In most cases use is made of the cheap petroleum spirit (benzine) available in large quantities, a special apparatus being employed on account of the great care necessary in view of the explosive and inflammable nature of the benzine. Among the apparatus for extracting fats, those of Deiss, Vohl, Seiffert, Lindner & Merz and Wegelin Hübner are best known, all of which are described in the author's *Vegetable Fats and Oils.* The extraction of the comminuted bones is effected in precisely the same manner as there indicated for oil seeds and oil fruits.

Properties.—The bone fat obtained by merely boiling the bones is, unless perfectly fresh bones are used (and this is very rarely the case), of very inferior quality, dark yellow to light brown in colour and of repellent smell. The colour is due to the dark decomposition products of the putrefying bone cartilage, and the evil smell arises from similar products, fats in general being characterised by the affinity they exhibit for absorbing and retaining odoriferous substances.

Bone fat prepared by the steaming process differs little from the last-named class in point of colour, but considerably as regards smell. The same partly decomposed bones that, in the ordinary method of simple boiling, would yield a fat with a repellent smell, will, if steamed, give a much less unpleasant-smelling product, the difference being attributable to the high temperature employed, whereby the greater part of the malodorous substances is immediately vaporised.

The external appearance of the fat derived from bones varies considerably, that from perfectly fresh bones being pale yellow in colour and free from smell, whilst that from old bones is dark yellow to brown ; the consistency is either quite fluid, semi-fluid or like lard.

Benedikt gives the subjoined data for fat from perfectly fresh bones :—

Specific Gravity.—0·914-0·916 (Allen).

Melting-Point.—21 -22° C.

Setting-Point.—15° C., the temperature rising to 17° C. (Schaedler).

Saponification Value.—190·9 (Valenta).

Iodine Number of the Fatty Acids.—Crude fat, 37·4 ; refined fat, 55·7-57·3 (Morawski & Demski).

Uses of Bone Fat.—Solely technical ; in the soap and lubricating oil industries.

REFINING BONE FAT.

For the purpose of utilising bone fat it is essentially necessary to subject it to a process of purification to destroy the odours and colouring matters in the fat ; this process is carried out with either nitric acid or potassium bichromate, both of which exert a powerful oxidising action. In refining with nitric acid ½ to 2 parts by weight of acid are taken per 1000 parts of fat, the exact amount depending directly on the degree of impurity.

Wooden vats, containing wooden appliances for stirring, and fitted with a steam pipe at the bottom, are used. The fat to be purified is placed in a vat, where it is melted by steam and heated to 70°-80° C., the nitric acid being then run (from a glass vessel fitted with a glass tap) in a thin stream into the fat, during which time the stirrers are kept in continual motion. At intervals samples are drawn from the vat, cooled rapidly to cause them to set, and examined to obtain an idea of the condition of the fat. If the purification seems to be sufficient the stirrers are stopped and the fat washed, to which end it is allowed to run out in a thin stream into a second vat placed at a lower level and more than half full of water, besides being fitted with a steam pipe and set of stirrers. By admitting steam and simultaneously working the stirrers an intimate admixture of the fat and water is effected, and then after a short time the whole is left at rest, the water, after separation, being finally drawn off and replaced by a fresh supply, whilst the fat is washed again in the same manner and is then considered sufficiently purified.

By replacing the nitric acid by a mixture of equal parts of nitric acid and sulphuric acids, the purifying process is greatly accelerated, but the loss induced is greater than in the former case.

The second purifying process is that in which sulphuric acid and potassium bichromate are used. One part by weight of bichromate is dissolved in a very little water, and the solution placed in a stoneware vessel, 2 parts by weight of sulphuric acid being then poured and stirred in with a glass rod and the vessel left, covered up, for a couple of days. When sulphuric acid and potassium bichromate come in contact, chromic acid is liberated and dissolves in water to a red solution, whilst the potassium bisulphate formed at the same time crystallises out on the bottom of the vessel. From ½ to 2 per cent. of this chromic acid solution is added to the fat, according to the degree of impurity of the latter, and the stirrers are set in motion.

When the reaction is concluded the fat is washed, at first with only a small quantity of water, which becomes tinged with green or violet by the resulting chromic acid compounds, and these washings from various operations are collected and sold to colour manufacturers.

By using a sufficiency of bichromate, even a very impure bone fat can be rendered perfectly white and free from smell, and this class of product sells at such a good price as to well repay the high cost of refining.

Krätzer employs for bleaching bone fat a mixture of 500 parts by weight of the fat, warmed to 70°-75° C., and 5 parts of 30° soda lye containing 2·5 parts of common salt, and leaves the whole to stand for six to eight hours or over night. The clear settled fat is then cooled to 40° C. and to it are added successively a solution of 2·5 parts by weight of potassium bichromate and 7·5 to 10 parts of 22° fuming hydrochloric acid, mixed in by means of the stirrers, which are kept vigorously at work until the oil finally exhibits merely a green tinge with white froth, a sign that it is properly bleached. When finished, some 20 gallons or so of water at 75° C. are sprinkled over the surface from a watering-can and the whole covered up and left to stand, steam, if available, being blown in for ten to fifteen minutes.

By this method of washing with hot water or steam the acid remaining in the bone fat is washed out and carried down.

A bone fat bleached in this manner is, at the ordinary temperature, soft and lard-like in appearance, pure white or faint yellow in colour, and is specially characterised by the slowness with which it turns rancid when exposed to the air.

BONE OIL (KNOCHENÖL).

In order to obtain the bone oil from bone fat, which is done by precipitating the more readily congealable stearine group of fats, the fat is exposed to a low temperature (about 2° to 9° C.), whereby the solid fat separates out and the oil can be then poured off. According to the Polytechnic Society of

Berlin, much better results can be obtained by dissolving the fat in benzine and exposing the solution to cold. The clear liquid is poured away from the solid fat, and when freed from the solvent by distillation leaves pure bone oil.

ARTIFICIAL BUTTER, OLEOMARGARINE, ETC. (KUNSTBUTTER, MARGARINBUTTER, OLEOMARGARIN, SPARBUTTER).

By the above and similar designations is understood an artificial product obtained from constituents of beef tallow, prepared by special processes and worked up with milk and vegetable oils to a substance greatly resembling, or even identical with, natural butter in appearance, consistency and flavour.

The manufacture of artificial butter is a fairly simple process, but nevertheless entails the exercise of intelligence and care in order to fulfil all the requirements imposed. A few of the methods in use are given hereunder, and the reader is referred for fuller information to Lang's work on *Kunstbutter* (3rd edition, 1895).

MARGARINE MANUFACTURE IN FRANCE.

Villon describes the process as follows :—

The first operation consists in the separation of the so-called *premier jus* from the solid stearine and olein, melting at 38° C., and a liquid fat. The solid tallow is formed into pats, about 8 in. long by 7 in. wide and ½ in. thick, wrapped in linen cloths, and weighing some 2¼ lbs. (1 kilo) each. Two hundred of these pats are placed in a hydraulic press by placing on the lower plate (covered with a canvas cloth warmed to about 50° C.) a layer of 5 pats, these being covered with another cloth also warmed to 50° C. and surmounted in turn by a second set of 5 pats, and so on until the whole 200 are in position. The operations must be performed quickly, so that the cloths have not time to become cold. The separation of the oleomargarine begins without pressing, owing to the pressure of the cloths and to the warmth to which they are exposed, but as soon as the flow is observed to flag, the press is set to work, very slowly at first, the pressure being afterwards raised to 150 kilos (330 lbs.) and even to 175 kilos (385 lbs.).

The pressed tallow (*suif pressé*) remains behind in the cloths and is used for making stearine and tallow candles. The oleomargarine thus obtained is a yellow crystalline mass recalling ordinary butter, and is mixed with milk and cotton-seed oil or ground-nut (*arachis*) oil for churning. The proportions taken vary according to the quality in view, but the following have been ascertained :—

	I.	II.
Oleomargarine - - -	800 kilos	500 kilos (of 2·2 lbs.).
Milk - - - - -	500 litres	500 litres (of 0·22 gall.).
Cotton-seed Oil - - -	100 kilos	50 kilos.

The quantity of oil is adjusted according to the time of the year, 30 to 40 per cent. being used in winter, whilst in summer the oil is occasionally omitted altogether. Sesame oil is sometimes used, the object of the oil, of whatever kind, being to impart to the oleomargarine the suppleness of butter.

The oleomargarine is melted at 45° C., and the milk and oil are added at the same temperature, all being run into the churns through pipes from storage tanks several yards high, situated above the (wooden) churns. The materials are then thoroughly incorporated by means of dashers, the operation lasting about two hours, and the dashers being stopped towards the end in order that the quality of the product may be determined. The mixture is then allowed to run out of the churn through an inclined wooden trough into a large vat, a jet of cold water impinging on the mixture, as it falls from the trough, in order to granulate the margarine. In the vat the product floats in cold water, and is removed by gauze strainers or sieves and left to drain for about two hours in perforated vessels, whence it is transferred to revolving tables like those used for butter working, only larger. On these it is kneaded to express the milk, and the margarine thereby acquires the homogeneity of butter. The appearance of the product is improved by passing it in small portions through horizontal rotating fluted-roller working machines, after which it is made up into 1 lb. (or ½ kilo) pats. This method is the one most frequently employed, but the churned mixture can also be cooled by ice water from the ice-making machine, though this plan is not advantageous, since during the slight fermentation allowed to ensue before the mass is drained the flavour, *sui generis*, of a good margarine is, in this case, not attained.

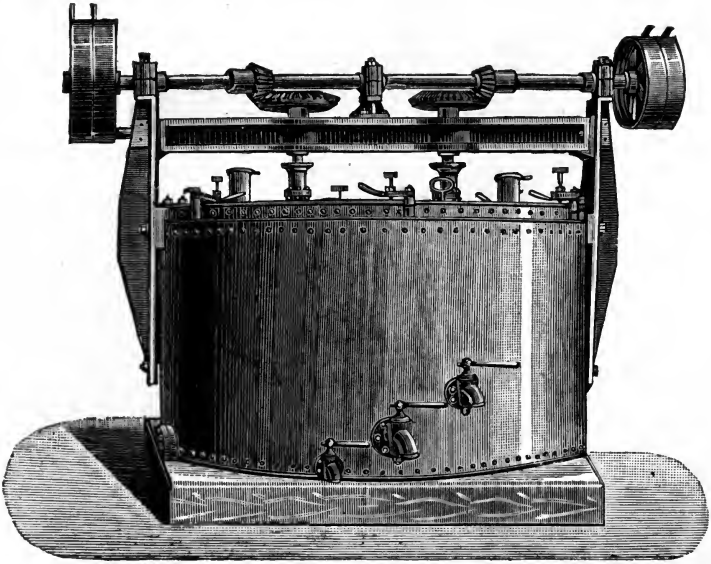


FIG. 54. Butter and Churning Machine (W. Rivoir, Offenbach-am-Main).

To obtain really good margarine the product must be allowed to set in small lumps enclosing small quantities of milk, and on this account the water used must not be too cold. A good butter flavour is developed by inoculating the margarine in the draining stage with a small quantity of a ferment obtained from artificial fermentation-cultures of good butter.

Henri Grasso of Herzogenbusch (Holland) designs and supplies margarine factories for a diurnal production of 1 to 3 tons of artificial butter. The entire plant consists of:—

1. One churn of 165 galls. (750 litres) capacity;

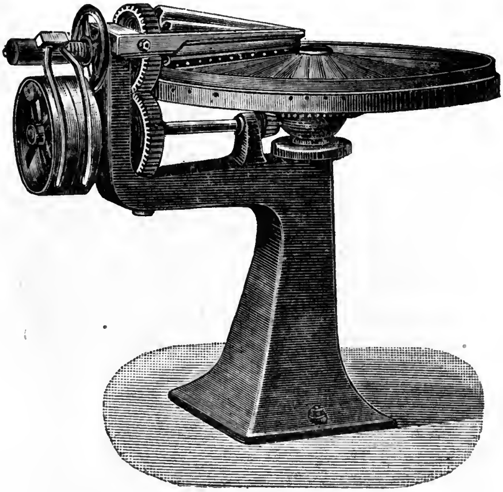


FIG. 55. Margarine Worker (W. Rivoir).

2. One ordinary roller worker with patent "Salamander" rollers, filling sack, flap and truck;
3. One margarine oil attemperator holding 165 galls.;
4. Four margarine melters holding 165 galls.;
5. One butter drier or mixing machine;
6. Three milk acidifiers, each holding 77 galls.;
7. One milk separator;
8. One pasteurising apparatus, several coolers for cream, skim milk and pasteurised milk;

9. One milk warmer ;
10. One churn for natural butter ;
11. One margarine oil pump, worked by hand ;
12. One granulating spray, with tap.

According to Grasso, the product is prepared as follows :—

The fresh milk is pasteurised, cooled, re-warmed, passed through the separator, cooled again and acidified with a pure culture (of ferment). It is then churned, and the resulting butter sold as "centrifuge" butter, the skim milk and residual buttermilk being used in making the margarine butter.

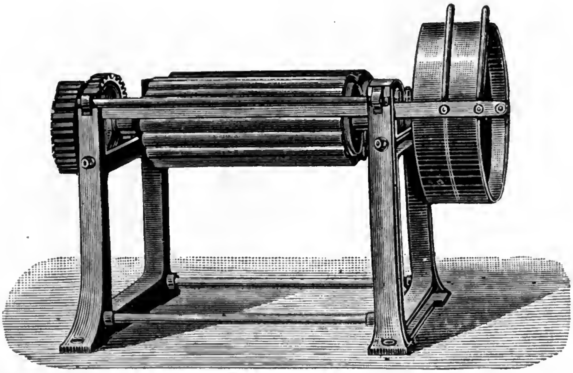


FIG. 56. Butter Mill with Fluted Rollers.

By a suitable selection of the raw materials, oleomargarine and oil, various qualities of margarine butter can be produced. The oleomargarine is melted in the margarine melter by means of hot water, the temperature employed depending on the composition of the oleomargarine used, being, when the latter is of lower quality and contains stearine, of course higher than when a purer material is used. The oil is not heated, but only warmed a little.

In the actual preparation of margarine butter a certain quantity of milk is put into the churn and churned for about ten minutes, the necessary amount of oleomargarine and oil being then added at a certain temperature and the mass mixed with alternate increases and diminutions of temperature, in order that it may be delivered at the end of the necessary time into the granulating pan, where it is granulated by the aid of ice water. When thoroughly cooled, the now solid product is shovelled into small trucks and conveyed to the roller machine, where it is worked (kneaded), this last operation being repeated a dozen times, after which the margarine is salted, passed twice through the butter drier and then packed.

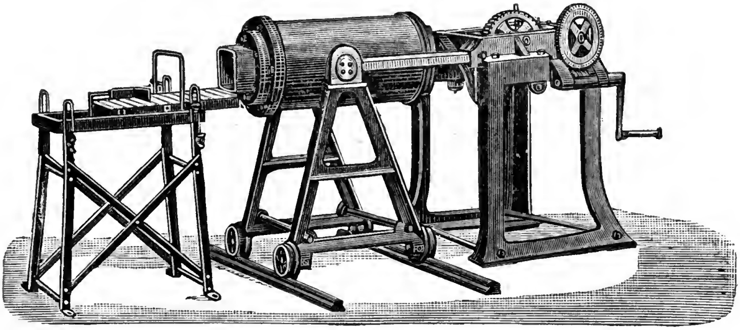


Fig. 57. Moulding Machine for Margarine (W. Rivoir).

"Kaiser Butter."

According to a communication issued by H. & M. Pataky, patent agents of Berlin, it has been established on the basis of scientific experiments that levulose and substances containing same, when incorporated with edible fats by a special process yield a preparation that, unlike other fats, needs no admixture with bile to form an emulsion in the alimentary canal. All edible fats liquefy, it is true, at the temperature of the body, but their emulsifying capacity is dependent on their intermixture with the biliary fluid in the intestines, and since the amount of this fluid is in most persons comparatively small, the ordinary edible fats are only to a small extent actually digested, *i.e.*, absorbed by the intestines. Of all the alimental fats hitherto known, good fresh butter is the easiest of digestion, owing to its superior capacity—in comparison with the others—of emulsifying with relatively low proportions of bile. If, now, edible fats be incorporated with levulose, they liquefy in the human stomach and form emulsions with water at temperatures even below 37° C., so that their digestion is thus ensured. The process is carried out in such a manner that the fats, warmed to about 70° C., are mixed with an addition of a solution of levulose at the same temperature, the mixture being rendered thoroughly intimate by continual stirring until cold, so that it emulsifies when shaken or otherwise agitated with water at temperatures from about 14° C. upwards. Butter mixed with levulose (or substances containing same) by this process is allowed to be sold as butter in Germany, and a patent has been granted for the "Kaiser butter" prepared in this manner. In addition to the properties already enumerated, "Kaiser butter" exhibits the advantages of superior flavour and keeping qualities. Consequently, the consumption of butter would be increased, and that of the butter substitutes at present vended decreased, by the introduction of this preparation, the price of which is even lower than that of ordinary butter.

PREPARATION OF ALIMENTAL FATS, ACCORDING TO JAHR AND MÜNZBERG.

According to the above-named inventors, easily digestible alimental fats may be prepared by intimately mixing fat, warmed to 70° C., with a solution of levulose at the same temperature, the liquids being stirred without interruption until cold. The mass thus obtained can be emulsified by shaking or otherwise agitating it with water at temperatures ranging from about 14° C. upwards.

FILBERT'S PROCESS.

J. H. Filbert's process for preparing alimental fats consists in the admixture of tallow and cotton-seed oil, the former being gradually liquefied at the lowest possible temperature and the oil added, whereupon the mixture is vigorously stirred and beaten in order to reduce the size of the oil globules still further and bring about their intimate incorporation. Simultaneously, air is blown through the mixture, so that the finished product is light in colour and the particles of cotton-seed oil and minute air bubbles are held in suspension in the solid tallow.

WINTER'S METHOD.

A. M. Winter took out an American patent for the following mixtures as alimental fats (! ! !) :—

1. Fatty substances and refined mineral oil mixed in such proportions as will produce a stiff mass ;
2. Refined mineral oil and animal or vegetable fats in proportions calculated to form a stiff mass ;
3. Refined mineral oil, oleostearine, tallow and vegetable oil (cotton-seed oil) ;
4. Sixty per cent. of refined mineral oil and 40 per cent. of fatty substances ;
5. Sixty per cent. of refined mineral oil, 30 per cent. of animal and 10 per cent. of vegetable fat ;
6. Sixty per cent. of refined mineral oil, 15 per cent. of oleostearine, 15 per cent. of tallow and 10 per cent. of cotton-seed oil.

HUMAN FAT.

The investigation of human fat is of merely scientific interest, and it can readily be understood that little is known on the subject. Chevreuil found this fat to consist of an olein and stearine, the latter differing from mutton stearine in yielding margaric acid instead of stearic acid. Heinz found, however, that the constitution was of a more complex character, and that in addition to palmitic and stearic acids other acids, one of them liquid, are present. The fat examined by Mitchell was freed from tissue at the lowest feasible temperature, was pale yellow in colour and somewhat softer in consistency than butter. When re-crystallised from ether, only a small precipitate was produced, and this, after washing (with ether) and drying, melted at 51·5° C. Under the microscope the crystals exhibited some resemblance to those frequently obtained in the form of fascicular bundles from lustrous lard, in that the individual crystals exhibited the characteristic chisel-shaped ends. The analysis gave:—

Fat.

Specific Gravity.—At 25° C. (water at 25° = 1), 0·9033.

Melting-Point.—17·05° C.

Setting-Point.—15° C.

Saponification Value.—145.

Saponification Equivalent.—287.

Reichert Number.—(2·5 grms.) 0·31 *n*-alkali.

Acid Number.—(1 grm.) 63 mgrms. KOH = 0·3 per cent. of oleic acid.

Bromine Number.—Heat, 11·3° C.

Iodine Number.—11·3 × 5·5 = 62·15.

Fatty Acids.

Melting-Point.—35·5° C.

Setting-Point.—30·5° C.

Iodine Number.—64.

Iodine Number of the Volatile Fatty Acids.—92·1.

Twitchell's modification of the Jean method of fractional precipitation was employed for determining the nature of the fatty acids, 1·9478 grms. of fatty acids (iodine number,

64) being dissolved in 25 c.c. of 95 per cent. alcohol and treated with 1·5 grms. of lead acetate dissolved in 10 c.c. of the same alcohol, and the flask well corked and left to stand all night. Next morning a little of the liquid was filtered off, the acids being recovered by agitation with ether and hydrochloric acid, and their iodine number ascertained. The precipitate was well washed with alcohol, the fatty acids recovered, dried, weighed and their iodine number determined, oxidation being in each case carefully guarded against. The results were :—

	Grams.	Iodine No.	Per Cent.
Solid acids - - - - -	0·9779	37	50·2
Liquid acids (by difference) -	0·9699	92	49·8

The acids from the filtrate were still liquid at 15° C.; those from the precipitate had a melting-point of 35·5° C. and a molecular weight of 278. From this may be calculated :—

Liquid acids in filtrate - - - - - - -	99·8 per cent.
,, ,, reckoned as oleic acid - - - $\frac{37 \times 50{\cdot}2}{100} = \frac{18{\cdot}57}{0{\cdot}9}$	20·06 ,,
Total liquid acids - - - - - - - -	70·4 ,,
Iodine number, $\frac{64 \times 100}{70{\cdot}4}$ - - - - -	90·9 ,,

Therefore, the liquid acids probably consist of oleic acid, with a small amount of unsaturated fatty acid, probably linolic acid.

So far as the solid acids are concerned, the high molecular weight of the lead precipitate (of which only 20 per cent. should be considered as liquid acids) leads to the conclusion that stearic acid or another high molecular acid is present.

The crystals obtained, after washing and drying, from the crystallisation of the fatty acids from 70 per cent. alcohol melt at 50·5° C., which is a lower melting-point than is exhibited by any other mixture of stearic and palmitic acids, according to Heintz' table, and indicates the presence of myristic acid, since the precipitate was entirely free from liquid acids. The filtrate on standing yielded a second precipitate, also melting at 50·5° C.

Human fat, according to these data, therefore consists of some 70 per cent. of liquid fatty acids, chiefly oleic acid, and 30 per cent. of solid acids, probably palmitic acid, together with small quantities of stearic and myristic acids and traces of lower volatile acids.

HORSE FAT, HORSE GREASE (PFERDEKAMMFETT, PFERDEFETT).

Raw Material.—Chiefly the fat found in the neck (under the mane) of the horse, and in addition all the fatty portions of the carcase.

Preparation.—The fat after separation from its integument is collected and melted—by steam if on a large scale, or simply by hot or boiling water in small works—then strained and placed to set in suitable vessels.

Properties.—The actual mane fat of the horse is pure white and inodorous, softer in consistency than lard, melts at 30° C. and consists of 70 parts of olein and 30 parts of a mixture of stearine and palmitin.

The other fat from this animal is thick, almost like pomade, and separates on standing into a solid portion and a supernatant liquid. At 10° C. it resembles lard, and at 8° C. tallow; it is of a dirty yellow-brown colour and possesses a characteristic fatty odour.

The marrow fat obtained from the large hollow bones of the horse is a waxy-yellow, greasy fat, becoming hard in the air; it begins to run at 65° C. and is at 86° C. thick like syrup. By the aid of soda a very solid white soap can be prepared therefrom.

Uses.—Medicinal: for ointments in veterinary medicine.

Cosmetic: for pomades intended to promote the growth of hair. Technical: for softening leather, lubricating machinery, wool softening, and the manufacture of soft soaps, for which it is specially adapted.

BEEF MARROW (RINDERMARK).

Raw Material.—The large hollow bones of the ox contain a fat (marrow) which is identical with tallow, and is indebted for its characteristic taste to the cellular tissues which accompanies.

Preparation.—The bones are opened, *i.e.*, split or sawn, whilst still fresh, and the marrow, which corresponds to the bone in shape, carefully collected. In old bones, no longer fresh, the marrow has no special value, and is then only classed as bone fat. It is carefully melted, separated from the cell tissue by straining and stored in a suitable manner.

Properties.—Melting-Point.—45° C.

Setting-Point.—35° C., the temperature rising thereon to 40° C. In the natural state it is of a reddish colour (owing to the numerous blood-vessels by which it is traversed), hard, tallowy and exhibits a granular structure when set after melting. It consists of about 70 per cent. of palmitin and stearine and 30 per cent. of olein, is imperfectly soluble in boiling alcohol and also harder to dissolve in ether than is the case with tallow; moreover, it becomes rancid more readily than the latter.

Uses.—For alimental purposes, as an addition to soups, which it strengthens; in cosmetics, for pomades, ointments, etc.

TURTLE OIL (SCHILDKRÖTENÖL).

Raw Material.—The eggs of the green and giant turtles of Jamaica and the Seychelles, and also those of the edible turtle. According to Brooks, it is obtained from the fat of these animals as well.

Preparation.—Turtle oil, or more correctly, turtle-egg oil, is prepared by crushing the eggs with a forked wooden instrument in an empty bucket and pouring water on the mass, whereupon, after a few hours' exposure to the heat of the sun, the oil collects on the surface of the water. Six thousand turtle eggs yield only 5 galls. of oil; and as 50,000 galls. of oil are annually despatched to Para from the Orinoco, the Amazon and the Rio Negro, and 60,000 galls. are consumed by the native population preparing the oil, it will be evident that the turtles, which frequent the same sandbanks from year to year and lay 120 eggs apiece three times during the season, have extraordinary reproductive capacities.

When turtle oil is obtained from the flesh by boiling, the yield is uncommonly large, a single turtle often producing 10 galls. of oil, so the output of 60,000 galls. at the Seychelle Islands is not very difficult of accomplishment.

In Jamaica, also, the oil is prepared from the flesh of the turtle, presumably from *Chelonia Cahonana*. Seychelle oil is superior in flavour, and might, if its alleged properties are substantiated, form a substitute for cod-liver oil.

Hog's Lard (Schweinefett, Schmalz).

Raw Material.—The fatty portions of the hog, and especially those lying beneath the skin and between the intestines. The quality of the fat varies with the part of the body from whence it is derived; that from the exterior fatty integument of the hog, surrounding the entire carcase of the animal immediately below the skin (especially on the back and sides), is more solid and curdy, though, at the same time, more easily melted out than that from the interior of the body along the ribs, the intestines and kidneys, which is generally known under the names of leaf, loin, kidney fat (Schmeer, Liesen, Lendenfett, Nierenfett, Filz). The proper preparation and assortment of hog's lard and the raw material therefor is very important. January and February are the best months, the fat being then more consistent than during the warmer seasons of the year. Apparently the colder season, as a result of increased respiration of the denser air, has an influence in rendering the deposited fat poorer in hydrogen and richer in carbon, the hydrogen, by reason of its greater affinity for oxygen, being the first to enter into combination with the latter during respiration at low temperatures. Winter fat is accordingly richer in stearine, whilst summer fat contains more olein. The method of feeding and the health of the animal also exert a not unimportant influence on the constitution of hog fat, so that soft and greasy fat is also met with in winter. Pigs fed exclusively on acorns always yield a somewhat yellowish fat. Lard in the greatest quantity and of the best quality, both as regards consistency and appearance, is supplied by the intestinal fat of young pigs, this fat consisting mainly of cell capsules enclosing the pure fat and requiring to be broken before the melting process.

Preparation.—Hog fat is prepared in the same manner as tallow, by carefully melting the raw material and separating it from the cellular tissue and other residual fleshy matter. The fatty substance intended for melting is freed as well as possible from all adherent pieces of skin, sinews and flesh, and then cut into small cubes with knives or in the cutting machine, the material so prepared being repeatedly washed with water until the washings run away clear and colourless, after which it is transferred to the melting pan. This is generally of well-tinned copper, and is heated by direct fire, though steam-jacketed enamelled iron or large stoneware pans may be employed. The melting fat is constantly stirred with large wooden paddles, the work being continued until the liquid has become perfectly clear and all the water is evaporated. The clear fat is then poured through straining cloths, stretched on frames, into the storage or transport vessels, and after being slightly cooled is stirred until it has become white and opaque, although still thickly fluid. If the fat were allowed to simply set by itself, the contraction occurring in congelation would give rise to fissures in the mass, which would admit air to the interior and thus unfavourably influence the keeping quality. When, on the other hand, it is stirred until completely set, then so much air is stirred in that all cannot escape, and rancidity is still further facilitated. The stirring must therefore be discontinued at the proper time, whilst the fat is still soft enough to run together without leaving any interstitial spaces. When this particular method of cooling is not adopted a quantity of oily fat congregates on the surface and, being readily liable to alteration by rancidity, exerts an unfavourable influence on the consistency of the subjacent mass.

The residual matters (fragments of tissue, greaves) left behind in the straining cloths and in the pan are heated again in the pan to a somewhat higher temperature and then pressed in a so-called greaves-press, leaving the solid portions behind as greaves. The resulting fat is generally somewhat coloured and possessed of a peculiar roast smell. In the large hog-slaughtering establishments in America the fat is generally melted in apparatus similar to that described on p. 116 *et seq.*, and heated by steam under pressure, the precautions necessary in the case of tallow melting being, however, dispensed with, owing to the absence of any unpleasant smell.

The greaves are used as an inferior food stuff and fed to cattle, or, when obtained in large quantities, employed for the manufacture of potassium ferrocyanide.

Properties.—Sp. gr. at 15° C., 0·931-0·932 (Hager), 0·9380; at 50° C., 0·8818; at 69° C., 0·8814; at 94° C., 0·8628 (Saussure); at 100° C. (water at 15° C. = 1), 0·861 (König).

Melting-Point.—26°-31° C. (Berzelius), 40·5° (Buff), 41·5°-42° (Wimmel), 42°-48° C. (König). It begins to set at 26° C., the thermometer rising to 30° C. (Schaedler).

Melting-Point of the Fatty Acids.—35° C.

Setting-Point of the Fatty Acids.—34° C. (Mayer).

Hehner Number.—96·15 (West Knight).

Saponification Value.—195·8 (Köttstorffer), 195·3-196·6 (Valenta).

Iodine Number.—59·0 (Hübl).

Hog fat consists of olein, palmitin and stearine, and contains, according to Allen and Thomson, 0·23 per cent. of unsaponifiable matters. The olein content—as calculated from the iodine number, 59·0—is 68·4 per cent.; Braconnet states it as 62 per cent. Hog fat very quickly turns rancid on exposure to air, and in that condition will absorb copper or lead from coppered vessels or those coated with lead enamels, and thereby becomes poisonous. To test for these metals the fat is digested with acetic acid, and a part of the acid treated with yellow prussiate of potash (potassium ferrocyanide). A brown coloration indicates copper, whilst lead is revealed by the white precipitate produced by dilute sulphuric acid in a second portion of the acid extract.

Hog fat is soluble in 27 parts of absolute alcohol or 35 parts of alcohol of sp. gr. 0·9128, also in ether, chloroform, carbon bisulphide, hot benzine and warm petroleum spirit. When fresh, it has a neutral or very faint acid reaction, and yields on saponification and subsequent decomposition of the product 8·8 per cent. of glycerine and 95·90 per cent. of stearic, palmitic and oleic acids. Of this 104·70 per cent., 4·7 per cent. represents water absorbed in the production of glycerine and acids.

The colour of hog's lard is white, granular and of salvy or pappy consistency, with an agreeable, rather sweet, fatty taste. It runs when held between the fingers, and on recooling after melting assumes a crystalline structure. It may be separated by pressure at 0° C. into a liquid, lard oil (schmalzöl specköl, huile de graisse), and a solid portion, solar-stearine, the latter product finding employment in candle-making.

Adulterations.—One of the most common methods of falsification is the incorporation of an excess of water to increase the weight. The readiest means of detecting this is by carefully melting a sample and leaving it to stand in a moderately warm place, whereupon the water will separate out. For increasing the weight of the fat the following additions are used: soda solution, potash solution and soda lye, all of which whiten the fat; also chalk, alum, clay, common salt and starch. Furthermore, alum or lime is added to lards already mixed with water, 1 per cent. of lime or 2-5 per cent. of alum being able to mask the presence of 12 or 15 per cent. of water. Other fats, notably beef tallow, are also added, and in America adulteration with cotton-seed oil is practised on a large scale.

Examination.—The method of detecting water has already been described. To identify chalk, clay or alum, a 100 grm. sample of the fat is melted at 69°-70° C. along with the same amount, or half as much again, of water, frequently stirred, and then set aside for a few hours. *Chalk* or *clay*, if present, will subside; *common salt* (sodium chloride) will be revealed by the white precipitate produced in the aqueous solution by acid silver nitrate; *alum*, by the voluminous precipitate with ammonia and the white precipitate with barium chloride; *soda* or *potash solution* or *lyes*, by the precipitates with calcium chloride; and the last-named bodies in particular by the yellow coloration given with mercuric chloride.

Admixtures of *starch* and *meal* give a blue coloration with iodine solution. Occasionally, tallow is employed to falsify lard, and can be identified by microscopic examination, since, whereas lard crystallises from an ethereal solution as rhomboidal lamellæ with angular corners cut off slantwise, the crystals of tallow are plum-shaped or curved like an S. An idea of the relative proportions of the two constituents can be obtained from the number of the crystals.

According to Schaedler, the manufacture of lard for alimental purposes, pursued on such a large scale in America, has unfortunately led to the shipment to Europe of enormous quantities of lard falsified by the addition of other fats. It is only in quite recent times that this adjunctive adulteration industry has somewhat receded, as a result of stringent regulations on the part of the American authorities. Nevertheless, a respectable amount is still sent over, particularly to Germany.

The detection of this form of adulteration necessitates a very searching investigation. The fat most frequently added to lard is refined cotton-seed oil, with which are mixed suitable quantities of beef tallow or beef stearine to compensate its high iodine number. The use of other oils, instead of that from cotton-seed, is naturally not precluded when the state of prices permits. A number of simple reagents have been proposed for the detection of such additions, among them being *alcoholic silver nitrate solution.* Pure lard will stand this test, but not lard that has been prepared, even with the most scrupulous precaution, on a small scale. Although the usual commercial brands will not stand this test, one is not therefore justified in considering them as necessarily adulterated, since very minute quantities of extraneous substances are sufficient to produce discoloration of the silver nitrate, and such quantities are always present in the commercial grades of lard. The same applies to molybdic acid solution, this test, also, being so delicate that the majority of commercial qualities of lard will not pass. It is performed as follows: To 1 grm. of the suspected fat, dissolved in about 5 c.c. of chloroform, are added 2 or 3 c.c. of a solution of pure sodium phospho-molybdate, and the whole shaken up. After a few minutes' rest the two liquids will have separated again, and the reagent solution overlaying the chloroform will be found coloured a more or less intense green to greenish-blue, according to the percentage of reducing substances in the lard. The same applies equally to the so-called Hirschsohn reaction for detecting cotton-seed oil, of which it is said to reveal down to 5 per cent. To 5 grms. of the suspected fat are added 5 or 6 drops of a solution of 1 grm. of gold chloride in 200 grms. of chloroform, the mixture being shaken up and immersed in boiling water for twenty minutes. In presence of cotton-seed oil the liquid will appear rose-colour to red by reflected light and greenish by transmitted light.

Lead acetate has also been recommended as a reagent, and is said to produce a more or less orange-red coloration when ammonia is added to the agitated mixture of acetate and melted fats. These reactions are all, however, uncertain, and the only sure means of forming an accurate decision is by a comprehensive examination embracing:—

1. The microscopic appearance of the melted and recrystallised fat;
2. The melting-point;
3. The saponification value;
4. The melting- and setting-points of the fatty acids;
5. The iodine number.

In connection with the iodine number of lard, it should be mentioned that it does not always enable an accurate conclusion to be drawn, the reason for this being the variable quantity of lard oil present, the iodine number of which is much higher than that of the fat. Moreover certain not unimportant deviations are exhibited in the lards obtained from various portions of the body of the hog. Thus Dietrich found lard from dripping to have an iodine number of 47·5 to 55·3 and that from bacon 60·0. In individual instances, however, the iodine number can be utilised in the determination of lard.

For the detection of solid fats in mixtures of vegetable and animal fats, Dr. Wainwright elaborated the following method :—

The mixture is subjected to pressure at the ordinary temperature (about 70° F.) of the laboratory, temperatures much higher or lower than this impairing the accuracy of the results, since at 60° F. large quantities of the compounds with higher melting-points are retained, whilst at 80° F. and above many of the lower melting constituents are removed. The method was specially devised for the separation of artificial lard composed of cotton-seed oil, hog's lard and stearine, and for the express purpose of determining the percentage of oleostearine, which, in presence of hog's lard, cannot be done by existing methods wherein use is made of the iodine number and other constants. By Wainwright's method, however, the estimation can be performed to within 1 per cent., a greater margin of error being, nevertheless, admissible until the method has been further elaborated.

Dr. A. Goske investigated hog's lard, particular regard being paid to the detection of tallow by crystallisation. The earlier experiments were performed on steam lard (American crude lard) and the so-called neutral lard (the edible lard) prepared therefrom, both of which can be readily examined for tallow by crystallisation. In the case of butchers' lard, other conditions obtain, the crystals forming herein exhibiting marked differences compared with those from American lard. By dissolving the fat in ether and allowing it to recrystallise, the crystals obtained in the absence of tallow are lamellar with sloping edges, whereas when tallow is present they take the form of aggregations of small needles. The result of the crystallisation is in a measure dependent on the temperature prevailing and on the amount of fat in the solution; the smaller the quantity of fat and the higher the temperature the better do the crystals come out. It is best to take not more than 1 grm. of lard and to leave it to stand at 12° to 13° C., since if the solution be set at lower temperatures (*e.g.*, 4° C. and under), good and characteristic crystals will never be obtained.

When the crystallisation has been satisfactorily performed, the crystals of pure steam lard appear, under the microscope, as large sharply-defined plates, often up to ¼ mm. wide, their mass being here and there interspersed with aggregations of long black-looking needles, though slight modifications of this ordinary type may occur. Lard containing tallow crystallises in small fascicles of needles starting from a common centre, and varying from brown to black in appearance. The hard crystalline aggregations observable are composed exclusively of beef stearine, the hog stearine remaining in solution, for which reason lamellæ are never observed when tallow is present. Latterly, oleomargarine is, on occasion, employed as an adulterant, in which event the appearance of the crystals as a whole differs from that presented in the case of lard mixed with press tallow.

Butchers' tallow shows a remarkable difference in crystalline habit, in that no true lard stearine lamellæ can be obtained therefrom, their presence being at most merely indicated. "Butchers' tallow crystallises in needles," which are considerably longer than tallow needles, frequently felted or fascicular, and occasionally resting on a common stalk. Goske's researches also aimed at elucidating the reason why American lard is richer in olein than butchers' lard, but failed to realise their object.

With regard to the detection of oil in lard, Goske partly abandoned the use of phospho-molybdate, since this reagent is reduced by any lard that is somewhat old. On the other hand, Becchi's reaction was found useful when performed in the following manner, fat that was as much as three or four months old, and had been left exposed and had thereby acquired a repellent smell, exhibiting no reducing action. In cotton-seed oil the reducing power appears to diminish with age. The reaction is performed in the manner recommended by the Italian Committee, the following solutions being used separately :—

(1) 1 grm. of silver nitrate dissolved in 200 c.c. of 98 per cent. alcohol, 40 c.c. of ether and 0·1 of nitrate acid;

(2) 15 c.c. of colza oil in 100 c.c. of amyl alcohol.

Equal parts (5 c.c.) of fat and solution No. 2 with $\frac{1}{2}$ c.c. of solution No. 1 are heated for a quarter of an hour in a briskly boiling water bath.

For observing the reaction the test tube is held in front of a sheet of white paper. However, in doubtful cases, where no decided brown coloration is produced, one must not rest contented with the Becchi reaction alone. Under these circumstances the pressure method recommended by Goske in 1892 finds employment. The fat, say 1 lb. (or about $\frac{1}{2}$ kilo), is melted and allowed to set gradually in an oven at 26° to 30° C., being then slowly pressed between cloths in a spindle press, and the reaction repeated with the expressed oil concurrently with a sample of the original fat. If the colour of both liquids is the same faint brownish-yellow, the presence of cotton-seed oil may be considered as almost indubitably proved.

Jean's method of testing hog fat and fatty oils is based both on the refractometer test for the liquid fatty acids of the product under examination and on the determination of their saponification value. The liquid fatty acids are isolated from the total fatty acids by conversion into zinc soaps (by agitating the carbon bisulphide solution with zinc oxide) and subsequently decomposing the compound. Hog fat mixed with vegetable oils can be recognised by its fatty acids producing a smaller deviation than − 30°, the saponification value being at the same time below 190-191.

The subjoined figures were obtained by E. Späth in the examination of hog fat, beef tallow and cotton-seed oil:—

	Iodine Number.	Acetyl Acid Number.
Hog fat, self-run - - -	58·7-59·8	201·7-203·1
Older hog fat - - - -	52·0-52·4	198·9-199·2
Alimental fat - - - -	63·8	196·0
Beef tallow, self-run - - -	43·3	196·9-199·0
Cotton-seed oil, fresh - -	102·6	193·3-196·2
,, ,, older - - -	99·7	193·0
Mixture: 60 parts hog fat, 20 parts beef tallow and 20 parts cotton-seed oil - - -	62·0	190·6-192·1

	Acetyl Saponification Value.	Acetyl Number.
Hog fat, self-run - - -	207·2-207·6	4·55-5·5
Older hog fat - - - -	204·3-205·2	5·4-6·0
Alimental fat - - - -	205·7	9·7
Beef tallow, self-run - - -	201·8-204·7	4·4-5·7
Cotton-seed oil, fresh - -	213·3-217·0	20·0-20·8
,, ,, older - - -	216·0	23·0
Mixture: 60 parts hog fat, 20 parts beef tallow and 20 parts cotton-seed oil - - -	200·2-204·3	10·4-12·2

Dr. Mansfeld says, with regard to the examination of hog fat: "The difficulties in testing the purity of hog fat reside, not merely in the manifold, and mostly complex, methods of falsification practised, but also in the great variations existing in the figures reported in the literature of the subject".

The ordinary examination extends, in addition to the tests for coarser admixtures (water, mineral matter, etc.), to the purity of the fat as well. For this purpose the determination of the iodine number and refractometer index occupy the first rank. The former exhibits (in the case of the hog fats dealt in at Vienna) none of the fluctuations reported in the literature of the subject. The fat obtained from the interior portions exhibits a constant iodine number of 59 to 62, and the refractometer index (Zeiss' butyro-refractometer) scales 50°-51° at 40° C. Deviations from these figures afford grounds for suspecting the fat, lower figures indicating an admixture of beef tallow, an adulteration common in Vienna. This is confirmed by the crystallisation test, for which purpose benzol has proved the most suitable solvent.

In testing for vegetable oils the Becchi and Welman's reactions are employed, but require a little care, since the reactions may be faintly manifested even by pure hog fat. Clear filtration of the fat is particularly essential. Since, in the case of complex adulterations, a fat may give a normal iodine number, these qualitative tests should be invariably performed. In such instances a more detailed examination of the fatty acids affords an explanation, as the following constants show :—

Melting-Point.—38°-40° C.

Setting-Point.—35°-38° C.

Iodine Number.—63-64.

Refractometer Index at 40° C.—34-36.

The quantitative calculation of the proportions in the mixture necessitates the preparation of the liquid fatty acids. A process differing somewhat from that hitherto employed for the preparation of the lead soaps, and one that is used in the laboratory of the Paris Bourse, is given below.

About 10 grms. of the solid fatty acids are dissolved in 100 c.c. of ether, and 3 grms. of zinc oxide are added, the whole being then well shaken up for some time : zinc soaps are formed, of which the oleates are soluble in ether. The solution is then filtered by the aid of an aspirator, the ether removed by distillation and the residue mixed with 20 c.c. of hot dilute hydrochloric acid (1:4). Thereupon it is washed twice with hot water in a separating funnel and filtered and dried as described above.

Pure hog fat gives the following figures :—

Iodine number of the oleic acid, about 92.

Refractometer index, 44-45.

In the case of mixtures containing vegetable oils, both sets of figures are considerably increased in consequence of the presence of linolic acids.

Uses.—Medicinal : for ointments ; cosmetic : for pomades, creams, etc. ; alimental purposes : as edible fat and for cooking and frying.

LARD OIL (SCHMALZÖL, SPECKÖL).

By pressing hog's lard at zero C. lard oil, which does not set even at comparatively low temperatures, is obtained, leaving behind tallow (margarine, palmitin and stearine). Lard oil is thinly fluid like olive oil, pale yellow, and still contains (according to the method used and care exercised in its preparation) very variable quantities of palmitin and stearine, on which account its specific gravity and setting-point fluctuate considerably. Commercial lard oils have a specific gravity of 0·9165 to 0·9200 at 15° C. and a setting-point of − 1° to − 5° C. This oil finds employment as an edible oil and for lubricating purposes, as well as extensive use for wool-softening, replacing olive oil and spermaceti owing to its lower price, and being also used in France, England and America for adulterating these oils. The solid portion left behind in the hydraulic press forms a very suitable material for candle-making, and as solar stearine—coming (like lard oil) principally from America (Cincinnati)—finds a market in England, France and Germany.

TALLOW, BEEF TALLOW (TALG, RINDSTALG, OCHSENTALG, UNSCHLITT).

Raw Material.—The fat of ruminating animals (oxen, cows, steers, calves), which is enclosed in the cellular tissue and is still commingled with particles of skin or blood in larger or smaller quantities. As soon as the beast has been slaughtered, flayed and cut up, the fat is sorted into crude prime (Rohkern) and crude cuttings (Rohausschnitt). The former, the kidney fat, comprises the greater coherent fat masses which are designated, according to their position in the body, as intestinal fat, heart fat, lung fat, neck fat, purse fat (from the scrotum) and kidney fat, and is almost pure fat, free from particles of blood and flesh.

To the second category belong the waste fats, copiously interspersed with portions of blood and skin, from the limbs, etc. These crude cuttings come into the melter's hands in a comparatively fresh state, whereas the waste bits separated from the meat in trimming up are collected and sometimes have begun to putrefy, by reason of the long time they have been saved up to make a respectable quantity for delivery to the melter. If only a little more care were taken in storing the fat, by hanging the pieces up to cool and dry separately instead of throwing them into a heap whilst still warm, the very rapid putrefaction of the particles of blood, flesh and cellular tissue would be prevented and the fat-melting process no longer attended with such malodorous exhalations.

Also, in tallow-melting works themselves, large parcels which cannot be worked up at once could be preserved, by suitable cold storage and salting, to postpone, for a few days at any rate, the decomposition of the nitrogenous matters. For the preservation of crude tallow destined for alimental purposes, Schaedler proposes the following method: The fat is placed in vats containing water and 3 to 4 per cent. of leaven and is there left, the leaven undergoing continual decomposition and thereby protecting the fat from atmospheric oxygen. The acids—acetic and lactic acid—formed, dissolve the animal membrane and expose the fat, so that the residue left behind in the ensuing process of melting is but small. The residual water must be treated like manure heap drainings.

Preparing the Tallow.—By melting the crude tallow and pressing the residual cellular tissue, particles of flesh, etc.

For the rational utilisation of the crude tallow it must be reduced to small pieces, because the fat is not merely mixed with tissue but also enclosed in cell capsules; by this treatment the capsules are ruptured and the outflow of the fat facilitated. The comminution—which is mostly into small cubes—is effected either on wooden blocks and with a straight-edged chopper or in a kind of stamping trough with a pestle or pounder having an S-shaped cutting edge, an arrangement such as is sometimes used for cutting up roots for fodder. Another form is a knife worked on a hinge with one hand, whilst the fat is laid on the block with the other. In England edge runners are used for crushing and breaking down the cellular tissue. Fat cutters with rotating knives (see Figs. 3 and 4) are suited for performing the operation by machinery.

Three different methods are pursued in melting out the fat :—

1. The ordinary melting in an open pan over direct fire (the so-called greaves method or dry rendering);

2. Melting with dilute sulphuric acid over direct fire (wet rendering);

3. Melting by steam or in a closed apparatus of any kind.

As in the case of other factories, tallow-melting works are subject to certain official sanitary regulations which either prohibit the work being carried on in inhabited districts or permit it only under restrictions chiefly concerned with the suppression of the insupportable exhalations attendant on this industry. Melting over direct fire is now confined to small works, larger factories employing only the methods specified under 2 and 3.

1. *Melting in Open Pans over Direct Fire* (*Rendering*).

In this, the oldest method of all, a sheet-iron or copper pan is set in brickwork so that the flame touches the bottom only, since otherwise the fatty mass would become too strongly heated. The crude tallow, along with a small percentage of water, is placed in the pan and the fire kindled; the fat soon begins to run and finally forms a liquid rendered somewhat milky in appearance by the water initially present in the tallow and that added thereto. The expansion of the fat, in liquefying, ruptures the cellular envelopes, which then, under the influence of the continual heat and the evaporation of the water, contract and form, as it were, crumbs (the greaves) floating about in the fatty mass, the latter by degrees becoming clear. According to the size of the pan and the strength of the fire, as well as the amount of water present, the operation lasts from one to several hours, the mass having to be continually stirred with wooden paddles to prevent the residual tissue subsiding to the bottom of the pan and becoming carbonised. When the fat flows quietly and seems clear the pan is emptied and the greaves separated, to which end a strong sieve of sheet-copper of a diameter corresponding with that of the pan is placed in the latter and pressed downwards by means of the handles, so that the liquid fat rises through the perforations whilst the greaves are forced to the bottom. The tallow is then ladled out or run off, through a tap at a convenient height at the side of the pan, into a wooden vat or other suitable vessel covered with a filter cloth stretched over a frame or laid on a perforated plate, so that any residual particles of tissue still in the fat are retained, and the tallow freed from all solid matter. If the tallow is to be refined at once it can be run off into a second pan standing at a lower level.

In the melting pan there remain the greaves with some adherent fat—it being impossible to remove all the fat, however well the copper sieve may have been forced into the mass—and these are now subjected to pressure, the contents of the pan being filled into press-bags of woollen or horsehair cloth which are then placed in the greaves press. One of the oldest forms of press employed for this purpose is the screw press shown in Fig. 58. In this the press-bag containing greaves is placed in the cylinder D, which is made in two halves connected by screws, and consists of plaited strong iron wire or perforated plate strengthened by iron

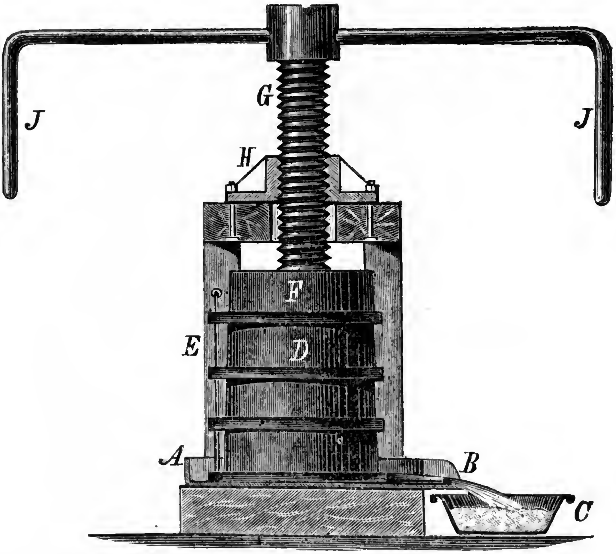


FIG. 58. Press for Greaves.—A, sheet-iron trough; B, discharge pipe; C, collecting dish; D, cylinder; E, frame; F, press head; G, screw spindle; H, screw socket; J, lever.

struts. It is open at both ends and stands in a sheet-iron trough A fitted with an outflow nozzle B. At the upper end the press head F fits accurately in the cylinder and is moved up and down by the strong screw spindle G working in the socket H on the cross beams of the press frame and driven by the lever J, thus exerting a strong pressure on the greaves and expressing the fat.

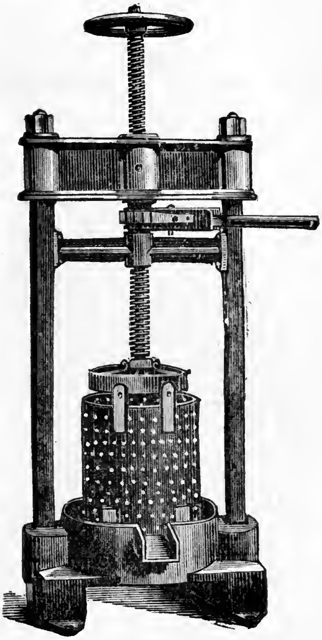


FIG. 59. Greaves Press with Ratchet Lever Gear.

Improved presses for greaves are displayed in Figs. 59 and 60, that with ratchet lever gear furnishing very good results. Other presses, notably hydraulic presses, may of course be also used for the same purpose.

The greaves presses are always placed near the melting pans or in some other warm situation, in order to prevent the tallow from setting. The yield obtained by melting crude tallow amounts to 80-82 per cent. of tallow and 10-15 per cent. of residue (greaves); very pure and dry crude tallows—kidney suet—yield 90 per cent. and upwards of pure tallow. The loaf or cake tallow is obtained from the melted tallow ladled out of the pan and poured into wooden vessels, the yellow-coloured product from the pressing of the greaves forming cask tallow.

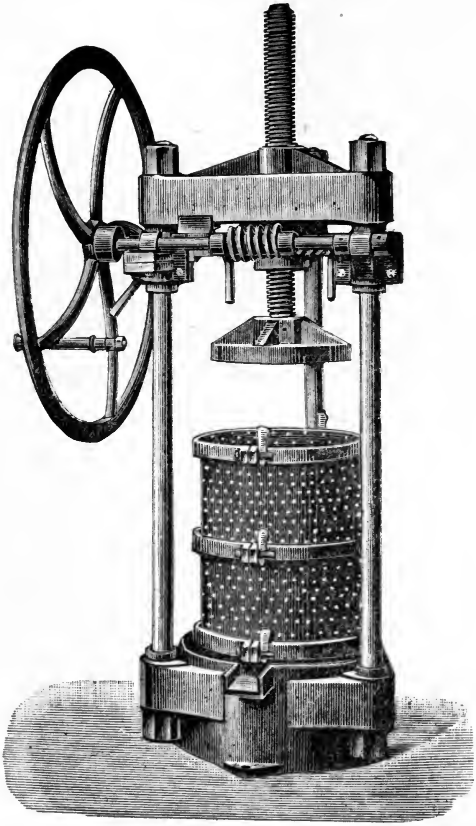


FIG. 60. Greaves Press.

Occasionally a weak brine is added to the tallow in the melting pan, but its sole action is to produce a rise of temperature. The pure white tallow is known as "virgin tallow," that from the press being "greave tallow" or "second runnings".

The greaves, even when most carefully pressed, still retain up to 10 per cent. of fat. Formerly the very brown or carbonised greaves were much used as fuel and the better kinds given to pigs and poultry; but in large works, where they are produced in quantity, they are now extracted by carbon bisulphide, benzine, etc., and the product employed as a lubricant. The residual greaves, which, when no carbonisation has occurred in the melting process, consist of pure cellular tissue, may be worked up for glue, ferrocyanide, ammonia, manure or nitrogenous charcoal.

As has already been mentioned, malodorous vapours and gases are evolved into the air during the melting of tallow in open pans and infect the neighbourhood. These gases and vapours contain, in addition to volatile acids (acetic acid and butyric acid), the constituents of the empyreumatic animal oils, such as ammonium cyanide, ammonium sulphide, sulphuretted hydrogen, pyridin, picolin, lutidin, etc. Acrolein vapours should not, however, occur, their formation requiring a higher temperature than is necessary for melting tallow.

The inconveniences resulting from the open melting of crude tallow can be obviated by means of suitable contrivances. These comprise a tight-fitting pan lid provided with a flue pipe, through which the vapours can be drawn into the smoke stack and discharged into the air at higher levels.

A stirring apparatus, worked from the outside, must, of course, be employed. The gases can also be exhausted direct by a current of air. Appliances constructed on these or similar principles are supplied by Thomson, Errard, D'Arcet, Wilson, Buff, Fourlé and others.

According to Schaedler, the process of melting along with caustic soda is greatly underestimated, notwithstanding that the malodorous fatty acids are, by this method, brought into combination. The temperature need not exceed 100° C., 100 parts of fat being mixed with an equal weight of a 1 to 1½ per cent. caustic soda lye and heated by a current of steam. The cellular tissue is greatly distended by the alkali, and the floating fat, after being kept in the liquid condition for a few hours to clarify, is washed with water, 95 per cent. of an inodorous fat being obtainable by this means. The alkaline water when subsequently treated with acids gives off an odour of the volatile fatty acids in the original fat. This method is, however, unsuitable for very old fats, ammonia being in such case evolved. The mass froths up greatly when heated and the separation of the fat from the emulsion of lye is attended with much difficulty.

2. *Melting with Dilute Sulphuric Acid.*

D'Arcet prefers to melt tallow along with dilute sulphuric acid, 100 parts of tallow being, as a rule, employed with 50 of water and 1 of sulphuric acid (specific gravity, 1·848). When the mixture has been heated during several hours, to such a degree that the dilute acid boils continuously, the total quantity of fat will be gradually obtained floating on the surface, because the cells of the fatty tissue are, for the most part, destroyed, and the fat liberated. On examining the greaves under the microscope it will be found that the still unbroken cells no longer contain fat, but are filled with dilute sulphuric acid, which has penetrated into the interior and expelled the fat thereform.

D'Arcet's process presents the advantage of recovering the *whole* of the fat without the necessity of pressing the greaves, since the latter merely contain dilute sulphuric acid. It is, however, an inconvenience in this process that the resulting greaves can no longer be exclusively employed as fodder, though it is erroneous to assert that they are altogether unfit for that purpose, since numerous experiments have demonstrated that such acid greaves, when mixed with other food stuffs, can very well be used for feeding pigs without the latter losing their appetite or the power of laying on flesh. The chief drawback to the D'Arcet process is that iron vessels, being rapidly corroded by the sulphuric acid, cannot be used, and recourse must be had to materials (*e.g.*, lead) unattacked or only inappreciably affected by this acid. To avoid making the vessels too heavy, as they would be if constructed of lead alone, iron pans are lined internally with sheet lead a few millimetres in thickness, the joints of the plates being of course closed by pure molten lead. When steam is available the treatment of tallow by the sulphuric acid process can be carried on in lead-lined wooden vats, or when wooden vessels are easily procurable the leaden lining may be omitted, since these vessels, especially when made of woods rich in resinous matter, can be used for a relatively long time.

STEIN'S TALLOW-MELTING PROCESS.

According to Stein, the pans serving for melting the tallow should be fitted with a grated false bottom to support the greaves and prevent their charring, the employment of stirrers thus becoming unnecessary. The pan is fitted with a lid perforated and covered with a linen cloth supporting a layer (3-3½ inches thick) of alternating strata of lime and charcoal, through which the evolved gases ascend and are thereby deodorised.

This disinfecting layer must be renewed each time the pan is charged afresh, a troublesome task and one disturbing the regularity of the work. Burning the vapours always affords the most satisfactory prospect.

ROVARD'S TALLOW-MELTING PROCESS.

Rovard employs for the destruction of the cellular tissue a substance, *viz.*, caustic soda, that acts even more energetically than sulphuric acid on organic substances. As is well known, caustic soda in common with the other caustic alkalis has the power of dissolving animal integuments with ease. Since, however, the alkalis also possess the power of saponifying fats, a considerable loss of fatty matter would ensue, from saponification, were a large quantity of caustic soda employed, soaps soluble in the water used for melting being formed ; but if the caustic alkali be employed merely in small proportion the saponification of the tallow need not be feared, very dilute solutions of alkali attacking the fat only after somewhat prolonged boiling, whilst the complete destruction of the cell capsules is accomplished much sooner.

The use of caustic soda is undoubtedly preferable to sulphuric acid in tallow melting, the yield of tallow obtained thereby being the highest possible. A drawback—though not one to be greatly emphasized—to this method is that the greaves are lost, and the liquor containing the decomposed cellular substance cannot be used for any other purpose than the watering of dung heaps.

The process, as originated by Rovard, contemplated the use of alkali carbonates, but there are many reasons for preferring to employ the alkali in the caustic condition, since though the carbonates have, it is true, the power of destroying the cellular tissue, the operation is a much more protracted one than in the case of caustic alkalis. Moreover, the use of carbonates in nowise precludes loss of fatty matter, the solution of these salts being capable of emulsifying the fat and dividing it into extremely fine globules, thus forming a milky liquid.

The quantities of caustic soda to be used in this process are relatively minute, 1 part dissolved in 100-200 parts of water being generally quite sufficient per 1000 parts of tallow. Only when the tallow under treatment contains a somewhat large proportion of cellular tissue may a rather larger quantity of caustic soda be taken; otherwise the boiling must be carried on for a longer time.

3. *Melting by Steam.*

Naturally, the melting of crude tallow by the aid of steam in closed vessels offers the greatest security for inodorous working and most complete utilisation of the materials, on which account this method cannot be too warmly recommended. Various appliances have been constructed for this object, notably those of Gellhorn, Flottmann & Co., Lockwood & Everitt, Rivoir, Heintschel and others, as already illustrated and fully described in an earlier section of the present work.

Properties of Tallow.—Beef tallow is hard and solid, pale yellow or white, tasteless and inodorous in the fresh state, but assuming after a short time a rather unpleasant characteristic smell, without, however, becoming rancid. It is insoluble in cold alcohol but dissolves in boiling alcohol of specific gravity 0·822, as also in ether, chloroform, warm benzine and ethereal oils. The elemental composition is :—

Carbon	76·50	per cent.
Hydrogen	11·91	,,
Oxygen	11·59	,,
	10·000	

Specific Gravity at 15° C.: 0·952-0·953 (Hager); at 100° C.: 0·860-0·8661 (Wolkenhaar), 0·860 (König).

Melting-Point.—42·5°-43·0° C.; older tallow: 43·5° (Schaedler); 45°-46° C., often 42°-43° but never below 40° C. (Wolkenhaar); 43·5°-45° C., setting at 27°-35° C., the temperature rising a few degrees without becoming constant (Rudorff).

Setting-Point.—37° C. (Chateau).

Melting-Point of the Free Fatty Acids.—45° C. (Hübl).

Setting-Point.—43·5°-45° C. (Dalican); 44·5° C. (De Scheepper and Geitel); 43° C. (Hübl).

Saponification Value.—196·5.

Reichert Number.—0·25.

Iodine Number (thermal).—40° C.

Beef tallow consists almost entirely of palmitin, stearine and olein, the percentage of the latter being calculable from the iodine number. According to the parts of the body from whence the tallow is derived, the proportions of olein, stearine and palmitin vary, the softest and richest in olein being the pure fat from the scrotum; the richest in stearine, and consequently the hardest, that from the intestines. Schaedler gives the average percentage of stearine plus palmitin as 66⅔ per cent.

Olein or tallow oil (talgöl), erroneously termed oleic or elaic acid, is obtained from beef tallow, as also from the other tallowy fats—mutton fat and goat fat.

This tallow oil is somewhat thick and pulpy, and is highly suitable for the manufacture of fine soaps, according to the colour of the commercial article. The press residue forms the ordinary stearine of commerce. In order to deprive the tallow of its entire content of olein, it is melted, then stirred continually until nearly cold and incorporated, by stirring, with 10 per cent. by volume of benzine or petroleum spirit. The mixture is left to cool in flat tin moulds, the cakes wrapped in press cloths and pressed between iron plates in the hydraulic press, whereby the olein dissolved in benzine or petroleum spirit is forced out, leaving stearine and palmitin behind. The benzine is driven off by distillation with direct steam and leaves the olein in a comparatively pure state.

The value of the olein (crude oleic acid) is greater the smaller the percentage of unsaponifiable substances it contains. Saponified olein is almost entirely free from these, and therefore commands a higher price than distilled olein.

There is a distinction between tallow oil (olein) and oleomargarine (styled "oleo"), the latter being prepared from fresh unmelted beef kidney fat by pressure, and used either direct as an edible or mixed with oil and milk and worked up into artificial butter.

Olein is a liquid solidifying in winter time, of a specific gravity of 0·90 at 15° C., and distillable, without decomposition, *in vacuo.* It is much more readily soluble than palmitin or stearine in absolute alcohol, but is insoluble in dilute alcohol. In the same way that oleic acid is converted by the action of nitrous acid into elaidic acid, so also olein, under the same conditions, passes over into a solid isomeric state, forming elaidin, consisting of crystalline nodules which melt at 32° C. according to Meyer, or 38° C. according to Duffy, and dissolve readily in ether, though almost insoluble in alcohol.

Oleomargarine has a specific gravity of 0·924-0·930 (Hager) at 15° C., and 0·859 (König) at 100° C.

Melting-Point of the Fatty Acids.—42·0° C.

Setting-Point.—39·8° C. (Hübl).

Iodine Number.—55·3 (Hübl), 50·0 (Moore).

Hehner Number.—95·56.

Saponification Value.—195·0 and 197·4.

Reichert Number.—0·4-0·6 (Cornwall).

The commercial grades are: Melted tallow, press tallow and margarine. In the Paris market tallow is sold on the "titer" of the setting-point of the fatty acids.

The subjoined "titers" were determined by Dalican for tallow and similar fats:—

Parisian tallow	43·5
Ordinary beef tallow	44·0
Beef tallow (kidney fat)	44·5
Ordinary mutton tallow	46·0
Mutton tallow (kidney fat)	48·0
Bone fat	42·5
Russian tallow	43·5
Beef tallow (Odessa)	44·5
Mutton tallow (Odessa)	45·0
Tallow from New York	43·5
Beef tallow from Buenos Ayres	44·5
Mutton tallow from Buenos Ayres	45·0
Florentine tallow	44·0
Viennese tallow	44·5

According to De Scheepper and Geitel, tallow and the fats used as adulterants therefor have the subjoined setting-points:—

Tallow	40°-46° C.
Margarine	38°-44° ,,
Oleomargarine, stearine	50·5° ,,
Mutton tallow	46·1° ,,
Beef tallow	44·5° ,,
"*Suif d'épluchures*" (a French commercial brand which, when dried, smells of sulphurous acid, is green in colour and is probably a mixture of animal fat with inferior olive oil)	40·3° C.
Bone fat	40·7°-42·3° ,,
Olive oil	40·05° ,,
Cotton-seed oil	34·0° ,,
Cocoa-nut oil	23·0° ,,
Stearine grease	44·0° ,,

ADULTERATIONS OF TALLOW.

Beef tallow is mostly adulterated with fats of low value, such as fish tallow (whale fat), bone fat, pot fat and latterly with distilled wool fat. According to Schaedler, such a falsification is hardly to be considered as fraudulent, provided the product be not sold under the general designation of tallow; the addition of these fats serves to lower the quality of the product, so that the manufacturer can supply industrials—for whose purposes the inferior quality of the article is no drawback—at lower rates. Adulteration of tallow with cheap fatty acids, notably those of wool fat, is indicated by the smell, which cannot be completely removed during the distillation of the wool fat.

Tallows falsified with fish tallow have their melting-point lowered considerably, and can be recognised in a superficial manner by the smell of fish oil evolved on gently melting the fat along with common salt. There are other adulterations practised by the addition of starch, potato flour or mineral substances, which can be identified, as in the case of hog fat; and cotton-seed oil is also used as an adulterant when the price permits.

EXAMINATION OF TALLOW.

Estimation of Moisture.—Five grams of the fat are placed in a tared glass beaker or basin containing a glass rod and dried, till constant, at 100° C., with frequent stirrings. If tallow be mixed with potash its absorptive capacity for water is increased. In such event the fat cannot be freed from water by drying at 100° C., so the best plan is to determine the content of fatty matter, impurities and potash, and estimate moisture by difference.

Non-fats (solid matters, fragments of skin, vegetable matter, dirt, etc.).—10-20 grams of fat are extracted in a flask with chloroform or benzol and then poured through a previously tared dry filter, washing with the same solvent until a drop of the liquid allowed to fall on paper leaves no grease spot. The solution is then dried at 100° C. and weighed. If on incinerating the residue a large ash is left, the sample has been mixed with some inorganic substance, chalk, clay, etc., the nature of which can be ascertained by the ordinary processes of qualitative analysis. When a copious organic residue is left after extraction, it is tested by moistening with iodine solution. A blue coloration indicates starchy matter (starch, flour or potato pulp), the presence of which is also detectable by microscopic examination. Moreover, 1 part of the suspected fat may be boiled with 2 parts of acidified water in a beaker for a few moments and then set in water at 40° C., so that the fat does not set too quickly for the impurities to subside. If iodine tincture be then added, a blue coloration is immediately developed. The starchy matters are freed only with some difficulty from fat by extraction, so that the weight of the dried residue after deduction of the ash does not exactly correspond to the amount of starch present.

Substances soluble in water are often left behind after the extraction with chloroform and can be identified (*e.g.*, common salt) by an analysis of the residue, or else they may be removed from the fat by taking a larger quantity of the latter—say 50 to 100 grams—and shaking it up in warm water to melt the solid fats, the mixture being then left at rest until separation into the two layers (fat and water) is complete. If this does not ensue, even after prolonged standing, but the fat remains partly in the form of an emulsion, the particles may be united by shaking up with ether; the resulting aqueous layer is then removed by the aid of a separating funnel and tested.

Sulphuric acid, remaining from the refining process, will be found in the aqueous extract, and may be estimated by titration with caustic soda, using methylorange as indicator, For detecting other dissolved substances the solution is evaporated and the residue examined.

Ethereal oils, in admixture with the fat, are removed by steaming and determined by the loss in weight. The distillate can be shaken up with ether, the latter evaporated and the residue examined qualitatively.

In unadulterated tallows the non-fats consist mainly of fragments of skin, gelatine and calcium phosphate.

Occasionally lard from cuttings is found to have been adulterated by the stirring in of lime whilst the fat was in the liquid state, the result being a hardening of the product by the formation of a lime soap. In the ether or chloroform extraction for the determination of non-fatty matter this admixture is left in the residue, which must then be examined for its estimation.

The examination of the dried and filtered fat is not confined merely to the detection of adulteration, but is also performed with the object of determining the value of the article.

Determining the Value of Tallow.—According to Dalican, the value of the tallow increases with its melting-point. Wolkenhaar considers that tallow having a melting-point of less than 40° C. is inadmissible, whereas Dalican, who, with greater correctness, determines the value by the setting-point of the fatty acids (tallow "titer"), gives 44° C. as the lowest limit therefor. The determination of the melting-point gives results varying considerably, according to the way the test is performed, so that it appears more suitable to determine the melting- and setting-points of the fatty acids obtained from the fat. The subjoined empirical table allows the percentage of stearic and oleic acids to be calculated from the setting-point of the fatty acids, the total yield of fatty acids being assumed as 95 per cent., the glycerine as 9·68 per cent. (corresponding to 4 per cent. of glycerine radicle C_3H_2) and the impurities and moisture as 1 per cent. :—

Setting-Point.	Stearic Acid. Per cent.	Oleic Acid. Per cent.
35	25·20	69·80
37	29·80	65·20
39	33·45	61·55
41	38·00	57·00
43	43·70	51·30
45	51·30	43·70
47	57·95	37·05
49	71·25	23·75
51	79·50	15·50
53	92·10	2·90

The constitution of the tallow can also be calculated from the iodine number, either the fat itself or the fatty acids therefrom being titrated. Theoretically, the iodine number of pure oleic acid is 90·07, that obtained experimentally being concordantly between 89·8 and 90·5. The iodine number of olein is 86·20. The iodine number of a fat being found, and expressed as i, then the olein percentage content O and the amount of oleic acid obtainable therefrom, E, can be calculated as follows :—

$$O = \frac{100}{86 \cdot 20} i \qquad E = \frac{100}{90 \cdot 07} i$$

or

$$O = 1 \cdot 1601\, i \qquad E = 1 \cdot 1102\, i$$

If i be the iodine number of the free fatty acids, then their acid content is also—

$$E = 1 \cdot 1102.$$

A high percentage of free fatty acids lowers the value of the tallow, owing to the dark colour of these acids when produced by lime saponification.

Detection of Fatty Adulterations.—The fatty adulterants of tallow are : paraffin, palm-kernel oil, cocoa-nut oil, cotton-seed stearine, wool fat, mutton tallow, resin and resin oils, fish tallow and bone fat.

Cocoa-Nut Oil and Palm-Kernel Oil.—The presence of these solid vegetable fats in tallow is revealed by the greatly increased saponification value, which is, for tallow, about 196, but for cocoa-nut oil 267·3 to 268·4 and for palm-kernel oil 247·6.

According to Rödiger these fats may be recognised in tallow by the property exhibited by their soaps of salting out with greater difficulty than the tallow soaps. The soda lye for saponification is prepared by mixing 75 grams of caustic soda of precisely 38° Bé. at 15° C. with 150 grams of water. 150 grams of tallow are heated to boiling along with 50 grams of water in a tared basin and qualified with 10 grams of soda lye, further additions of the latter being deferred until the first dose has been absorbed by the fat, which can be ascertained by taking a small sample out of the centre of the boiling soap solution by the wooden spatula employed for stirring and allowing it to run from the spatula. If the mass breaks raggedly or draws out in viscid threads (which will be the case after further additions of lye), then the alkali has been absorbed, whilst in the contrary event a clear watery liquid will drip from the spatula after the turbid mass has run off. If this appearance does not alter, even after prolonged boiling, more water is added. When the operator is inexperienced he should continue the boiling for at least half an hour after all the 225 c.c. of lye have been used up (which is always the case), replacing, from time to time, the water lost by evaporation. The mass will then run off in a fairly viscid condition, and water must be added to make up the total initial volume of 425 c.c., 38° Bé. soda lye being afterwards added by drops from a weighed flaskful until a clear drop of lye appears on the dropping sample of soap. This occurs when the following quantities of lye have been added :—

Viennese beef tallow - - - - - - -	25 grams of lye
Beef tallow with 5 per cent. of palm-kernel oil -	29 ,, ,,
,, ,, 10 ,, ,, ,, -	37 ,, ,,
,, ,, 15 ,, ,, ,, -	42 ,, ,,
,, ,, 20 ,, ,, ,, -	45·5 ,, ,,

so that as low as 5 per cent. of palm-kernel oil can be detected by this means.

Distilled Wool Fat.—To detect this fat, which, according to Leopold Mayer, is employed to adulterate tallow, the sample is saponified and shaken up with ether, the residue left after evaporating the ether being tested for cholesterin with hydrochloric acid and ferric chloride. As no other fat contains such a large proportion of cholesterin, this test is perfectly reliable. There are no tri-glycerides in distilled wool fat, only free fatty acids, and, consequently, tallow adulterated with this fat will have a very high free fatty acid content. The fatty acids isolated from such a sample will become yellow in a few days' time and exhibit the characteristic smell of wool fat, due to the presence of volatile fatty acids.

Cotton Oil or Cotton-Seed Stearine.—Tallow falsified with cotton-seed oil or the stearine obtained therefrom will assume a red to red-brown coloration on treating 5 grams of the melted sample with 15 drops of nitric acid (specific gravity, 1·380) and shaking up briskly. On the other hand, pure beef or mutton tallow under this treatment will remain pure white, and palm-kernel oil and other fats show only a yellow coloration. According to Wolkenhaar this reaction is unreliable, since pure, but carelessly melted, samples of tallow behave similarly, and the test is only to some extent definitive when the melting-point of the sample is below 40° C. and at the same time the specific gravity above 0·861. It would be advisable to carefully filter such impure tallows, in order to remove the staining impurities before applying the test.

Cracan remarks in his treatise, that in the ordinary methods of testing beef tallow the quantitative reactions are not always sufficient, since it is easily possible by suitable mixtures to arbitrarily produce an article exhibiting the constants relied on as indicating purity. He elaborated a few reactions (given below) specially for the case of Japan wax and for vegetable waxes in general, in respect of which he opined that adulterations of tallow therewith were not infrequent, such falsifications being, however, scarcely to be apprehended in the present low prices of tallow and high rates prevailing for vegetable waxes.

It seems an important characteristic of all waxes to be very slightly soluble in cold ether. Nevertheless, tallow stearine is also but slightly soluble in the same reagent and will also be precipitated along with any wax, though it is always an advantage to have those constituents of tallow that are readily soluble in ether separated from those only soluble with difficulty therein. Cracan proceeded by warming a large sample of the tallow under examination in a beaker until melted right through and then adding six to eight times the quantity of ether, whereby the whole of the tallow entered into solution, but at the end of about half an hour the liquid began to turn turbid and deposited a fine white precipitate. This was filtered off and repeatedly washed with cold ether until the washings ceased to leave a grease spot on paper, and the precipitate was then warmed, until melted, in a porcelain basin. Here it was found that some of these melted masses were white, others grey, the former being the case with products obtained from pure tallows and therefore consisting of pure tallow stearine, whereas a grey product resulted from the treatment in the prescribed manner of a so-called " South American beef tallow ". It was also found that pure tallow stearine was difficult to remove from the sides of the basin, even after a lapse of several days, whilst the product from the South American beef tallow separated very easily and came away spontaneously in a few hours' time. A slight degree of contraction was noticeable in both products, but was much greater in the second than in the pure tallow stearine. In the latter the contraction was more apparent by reason of the fissures developed in the mass, which was not the case with the South American article. The product from the South American beef tallow therefore exhibited a higher degree of cohesion, that from pure tallow stearine, on the other hand, manifesting a greater amount of adhesion to the walls of the basin.

Furthermore, pure tallow stearine yields on saponification a white soap, Japanese wax giving a yellow soap, and this phenomenon was also observed in several other, but by no means in all, kinds of commercial tallow. However, the kinds producing yellow soaps, all, without exception, answered to the following reactions, the contrary being the case in every instance with the kinds yielding white soaps—a circumstance which is, at the least, very striking. That many chemists have failed to perceive this yellow coloration is not remarkable, seeing that the indicator—phenolphthalein—employed in determining the saponification value naturally masks by its own colour the yellow tinge of the saponification product. It is therefore urgently recommended that all experts should in experiments of this nature perform a saponification test without the use of an indicator.

The reaction is most successfully obtained when about 5 c.c. of caustic potash are heated in a small porcelain basin and a little of the sample added thereto. If some 5 c.c. of ammonia be heated in a test tube and 3 decigrams of pure tallow stearine be added and shaken up, merely a faint turbidity is imparted to the liquid, but if the same treatment be applied to Japan wax an intensely white milky liniment is produced, and the same result is obtained with mixtures of Japan wax and tallow stearine.

When a little nitric acid, or aqua regia, is heated in a test tube and a little pure tallow stearine added thereto, no change of colour is observable, either during boiling or after recooling, but the stearine remains just as white as before. Vegetable waxes, however, when treated in this way, quickly turn yellow, and fumes of NO are evolved on heating. The same occurs in a lesser degree when mixtures of vegetable waxes and tallow stearine are employed.

THE REFINING, HARDENING AND BLEACHING OF TALLOW.

The tallow obtained from the crude fat by melting by one or the other methods mentioned is, even when carefully strained, however, not free from admixed undissolved substances, *i.e.*, solid matters, and therefore cannot be used for all technical purposes. Though well adapted for the preparation of ordinary soaps, candles, etc., it is unsuitable for fine toilet soaps, and for this purpose requires to be refined.

The refining of tallow consists in melting the same, in presence of water, over a fire or by means of steam, with or without the addition of certain chemicals reputed to exert a purifying influence. The simplest and oldest method is by one or more re-meltings in an open pan over direct fire and with an addition of 5 per cent. of water; the steam melting process, wherein a current of steam is passed into the melted fat, is new. It is an essential condition of the old clarifying process that the water should boil without ceasing and be thoroughly mixed with the fat by means of stirrers worked by hand or mechanical means, so that the latter substance is kept in a state of emulsion. When this mixing has continued for an hour the fire is drawn and the contents of the pan left at rest. During the slow cooling of the mass the lighter impurities rise to the surface and are skimmed off with a very fine strainer; the heavier and bulky impurities, on the other hand, sink to the bottom, as does also the water, so that a mucilaginous layer of dirt and fat is formed between the strata of fat and water.

The precipitation can, of course, only be complete provided the cooling of the tallow proceeds with extraordinary slowness. For this reason a very slow fire is kept up under the pan, or else the latter is, by being covered up with a lid, cloths, etc., kept from cooling down too quickly. Generally speaking, the fat in a pan of medium size will require about twelve hours to clarify thoroughly. The purified tallow is then skimmed off, or drawn off, through a tap at the side, and is placed in the transport packages, or if a second clarification is desired, transferred to another pan. Very often common salt, alum, salammoniac, etc., are added to the water used for re-melting, an aqueous liquid of unusually high density being thus obtained, from which the fat separates more easily than from ordinary water.

When steam is employed for clarifying it permeates the tallow, liquefies it and forces it through a strainer of very fine mesh, which keeps back the impurities.

In addition to these two principal methods, others have been proposed with the object, partly of purifying, partly of hardening and bleaching, and partly of sweetening the tallow by freeing it from unpleasant adherent smells. To effect the latter object (the cause of the smell being usually due to rancid fatty acids) the tallow is melted along with a solution of soda or borax, the *modus operandi* being otherwise exactly the same as when water alone is used.

Hardening the tallow is effected by various means. Apart from the old urine process (employed in slow-going soap-boiling establishments), the hardening process is based on a partial conversion of the olein in the tallow into solid elaidin by the action of acids, particularly nitrous acid. Alum, dilute sulphuric acid, potassium bichromate and manganese dioxide are also employed for hardening tallow, the products in any case being oxy-fatty acids formed by the action of oxygen, whereby the final product is rendered harder and more brittle, and at the same time whiter in colour and almost inodorous.

According to one prescription, a mixture of 500 grams of concentrated sulphuric acid and 500 grams of concentrated nitric acid is stirred into 100 kilos of melted tallow, and after allowing the acid mixture to react for a certain time is washed out again with pure water until the reaction is perfectly neutral, the tallow being finally heated over a gentle fire till all the water is evaporated.

When oxidising agents are employed, vapours are always evolved which contain whole groups of the volatile fatty acids: butyric, valeric, caproic and caprylic acids. Under the influence of nitrous acid, on the other hand, the reduction products of this acid appear in great quantity, and hydrocyanic acid is never wanting. For this reason, hardening with this reagent can only be effected in closed vessels and the gases must be suitably led away and rendered innocuous.

If the tallow obtained from crude tallow by melting at 60°-65° C. be allowed to crystallise at 35° C. and is then pressed, "prime press tallow" is obtained, whilst crude cuttings yield under similar treatment "press tallow seconds," the expressed liquid portion being in the former case classed as "prime margarine" and in the latter "margarine seconds".

The liquid portions of tallow can also be separated from the solids without pressure, since the solid crystalline bodies have higher melting- and setting-points than the liquid substances. To effect this separation the tallow is melted in large quantities (two to three tons at a time) by the aid of steam coils in large wooden vats, the vessels being then closed and left at rest for eight or ten days at a room temperature about 1° or 2° C. under the melting-point of the tallow. The fat has time to cool down very gradually, and the solid fatty acids crystallise in hard granules out of the liquid mass, settling on the walls and bottom of the vats in large conglomerate cauliflower-like aggregations. The liquid portion, the tallow oil, remains clear in the centre of the vessels and is then poured off, the crystalline lumps being left a while to drain and afterwards melted in water, poured out and allowed to set. In this way a product resembling press tallow is obtained. Nevertheless, neither this nor press tallow rightly deserves the name of "hardened tallow," since they are no longer tallow in its pristine state, *viz.*, stearine, palmitin and olein, but consist merely of stearine and palmitin, and therefore have an altogether different constitution.

In order to increase the whiteness of the product tallow is frequently *bleached*, the operation being oftentimes combined with the hardening process. Bleaching is effected exclusively with chemicals, *viz.*, chromic acid, manganese dioxide and hypochlorites. The various methods will be merely briefly mentioned in this place, having been already fully described in the author's *Vegetable Fats and Oils.*

1. *Bleaching with Chromic Acid or Potassium Bichromate.* —100 kilos of the tallow to be bleached are melted along with 1 kilo (2·2 lbs.) of sulphuric acid previously diluted with 6 litres (1·32 galls.) of water ; thereupon 500 grams (1·1 lbs.) of powdered red chromate of potash are added and the whole gradually raised to boiling. When cold, the deposited acid liquor is drawn off, and the tallow re-melted with water and washed in the warm until no further reaction is discernible.

2. *Manganese Dioxide and Sulphuric Acid.*—To 100 kilos of tallow is added 1 litre of concentrated sulphuric acid diluted with 30 litres of water, the fat being then melted and mixed with 1 kilo of the strongest manganese dioxide. The boiling mass is at first turned black by the manganese compound, then bluish, and finally (when the latter is completely decomposed) white. It is then left to cool, the bleach liquor drawn off, and the tallow freed from the chemicals by repeated meltings with water.

3. *With Hypochlorites.*—100 kilos of tallow are heated along with a solution of 1 kilo of soda in 10 litres of water, until the tallow is melted, a clear solution of 1 kilo of bleaching powder in 7 litres of water being stirred in and the mixture raised to boiling, whereupon sufficient dilute sulphuric acid to produce a faintly acid reaction is gradually and carefully incorporated therewith. After standing, the

aqueous liquor is drawn off and the (melted) fat washed with water until no more acid can be detected.

Since, in the two last-named bleaching processes, noxious vapours producing coughing may under certain circumstances be given off, the operation must always be carried on with the bleaching vat placed under a metal cover discharging into the open air.

Uses of Tallow.—Medicinal: for ointments; cosmetic: for pomades; as a food-stuff: for cooking and frying, and in a special form as a substitute for butter; technical: for candles, soaps and lubricants of various kinds.

ANIMAL OIL (THIERÖL).

RECTIFIED DIPPEL'S OIL OR OLEUM ANIMALE FŒTIDUM DIPPELI.

Raw Material.—The tar resulting from the dry distillation of bones.

Preparation.—The crude bone tar is placed in a still connected with a worm condenser. Liquid distils over rather quickly at first, and when it begins to come over less rapidly the fire is made up stronger, so that finally nothing remains in the still but an inflated black residue consisting of carbon, which is utilised for fuel. The distillate is pale to dark yellow in colour, of oily appearance, and characterised by the property of fluorescence it exhibits, the surface of the oil, when viewed at a certain angle, displaying a coloration inclining to blue or red. It should be mentioned that when a parcel of bone tar is once in work after the first distillation, it must be worked up completely without cessation, since otherwise the oil will turn brown by oxidation during storage.

The distillate is shaken up with strong hydrochloric acid, then separated therefrom, washed with water and rectified in glass retorts. By this means a series of bodies, which readily decompose and give rise to dark colorations, are destroyed, and it then becomes easier to prepare an oil that will remain light-coloured.

Since the action of oxygen is increased by high temperatures, an arrangement has been devised for re-distilling the first distillate—after the acid treatment—in a current of carbonic acid (carbon dioxide), in which case a copper vessel may be used for rectifying. The current of carbonic acid gas must, however, be strong enough to fill the receiver in which the distillate is collected, in order to keep the animal oil out of contact with the air. By adhering to these precautions the distillate from the crude oil may be made to yield, after two rectifications, a product which is almost colourless, and will remain fairly so if air be excluded. On exposure to the air it becomes dark-coloured, even though several times rectified; to prevent which discoloration, as far as possible, the oil should be stored, after rectifying, in air-tight bottles.

Properties.—Thin flowing and pale yellow when fresh, but brownish-black, from oxidation, when aged, with repellent smell. On treatment with sulphuric acid it is rapidly converted into brown masses.

Uses.—Medicinal: as a popular curative agent; technical: in the (sheep's) wool-dyeing industry.

FISH OILS (THRANE).

The fish oils are those liquid animal fats that are obtained from the fatty accumulations in the bodies of the large marine mammals; from the liver of various smaller or larger fishes; and finally by pressing a certain class of fishes, all inhabiting salt water.

All fish oils are, at the ordinary temperature, more or less fluid, pale yellow to dark blackish-brown in colour, and mostly endowed with a suffocating, more or less disagreeable smell and taste. Of the fish oils—whose chemical constitution is still insufficiently known—one portion is classed with the liquid waxes (sperm oil and the spermaceti prepared therefrom), and they are all very easily distinguished, by their behaviour on saponification, from the remaining oils and fats.

Both these products are devoid of glycerides, and contain instead, ethers of the higher fatty alcohols; and shark oil and all the marine animal oils with a specific gravity below 0·080 at 15° C. may be classified in the same group, since the great majority of the glycerides have a higher specific gravity than 0·914. Little is known respecting the fatty acids occurring in the form of tri-glycerides in fish oils. The place of the oleic acid found in other oils seems to be occupied here by physetoleic acid, but it follows from the very high iodine number of fish oils, that large quantities of a glyceride of an acid poorer in hydrogen are present; this cannot, however, be linolic acid, because fish oils are not endowed with drying properties.

Most of the fish oils are blackened by gaseous chlorine, whereas all other fats and oils are bleached by this reagent. The true and, partly, the wax-like fish oils as well give highly characteristic colour reactions: caustic soda of specific gravity 1·34 and syrupy phosphoric acid produce a red coloration; nitric acid, sulphuric acid and nitrosulphuric acid give black or violet-black colorations.

A large number of fish oils are met with in commerce and are classified according as they are derived from the carcase fat (blubber), the fatty liver or the whole fish, and also according to the genus of the animal yielding them. They are all employed either for medicinal (liver oil) or technical purposes.

By the term fish—or train — tallow (Thrantalg) are indicated the solid fats (stearines) separating out from fish oils at temperatures near freezing-point, or obtained by pressure at such temperatures. They also occur under the name of "whale fat," whilst the liquid portions are known as "expressed whale oil" (chiefly consisting of physetolein), also erroneously termed spermaceti oil.

The fish oils met with in commerce may be classified as follows:—

1. *Whale oils* (train or blubber oils): whale, sperm whale, fin-back whale, Arctic sperm, dolphin, porpoise, walrus, round-headed dolphin oil.

2. *Seal oils:* Archangel, Greenland, Newfoundland, South Sea, Caspian seal oil, walrus and Swedish "Three crown" oil.

3. *Fish oils:* herring, sprat, pilchard, sardine, sardella, menhaden oil, Swedish, Russian, Italian, Spanish fish oil.

4. *Liver oils:* cod-liver oil, coal-fish oil, merlangus oil, pollack oil, sea-pike oil, shark's-liver oil, ray oil, ray-liver oil, Japan fish oil.

The fish oils obtained from the blubber of the entire fish, or portions thereof, by boiling, contain in their natural state more or less animal gelatine (glue) derived from cartilaginous matter. The various kinds of fish oil have different odours and flavours, which are indescribable, but when experienced a few times, fix themselves in the memory and form (the taste especially) a sure, if not agreeable, means of recognition.

The various fish oils—pure seal oil, whale oil, liver oil, train oil—can be distinguished by the aid of fuming nitric acid and sulphuric acid, the colour reactions obtained being nevertheless unreliable.

The violet colorations given by liver oils with sulphuric acid do not result from the presence of the biliary colouring matters, but, according to Salkowsky, cholesterin, the colouring matter (lipochrome) discovered by Kühne and the fatty acids themselves take part therein. Further assistance in differentiation, and perhaps the detection of adulteration, should be afforded by the difference of solubility in hot alcohol, in that the latter will take up 4 per cent. of fish oil, 7 per cent. of liver oil, 15 per cent. of seal oil and its own volume of whale (blubber) oil.

The fish oils are, for the most, only adulterated with lower grade train oils, and resin oil; the medicinal oils rarely with vegetable oils (such as sesame and cotton-seed oil), which latter, by the way, can be detected by the elaidin reaction, fish oils remaining clear and transparent whilst the last-named oils deposit elaidin after some time, the fatty layer being thereby rendered thick and opaque.

Further particulars are given under the different headings relating to fish oils.

COLOUR REACTIONS OF THE FISH OILS WITH ACIDS.

	Fuming nitric acid (specific gravity 1·45).	Sulphuric acid (specific gravity 1·6-1·70).	Nitric and sulphuric acids 1 : 1.
Seal oil.	Red-brown.	Reddish-yellow, then reddish-brown, finally brown-red (blood colour).	Reddish, then brown.
Whale oil.	Brownish, then brown, finally blackish-brown.	Brown, then blackish-brown.	Yellow, then reddish, later a dirty brown.
Liver oil.	Blood red, then brownish-red to brown.	Violet to blackish-violet.	Yellow-red, then brick-red, finally red-brown with violet tinge.
Fish oil.	Brown.	At first greenish, then brown, finally quite black.	Yellow, then greenish, subsequently brown.

1. *Whale Oils* (*Train or Blubber Oils*) (*Walthrane*).

Raw Material.—The fat of marine mammalia—sea cow, walrus, manatee, dolphin, porpoise, sperm whale, Arctic sperm whale, Greenland whale.

Preparation.—The dead carcases are hauled on deck or, if near the land, on shore, and the cutting out of the blubber is at once begun. The men stand on small platforms let down the side of the vessel, and cut strips, about a yard wide, in the blubber (which is 18 to 30 inches thick) right round the carcase, over the back and belly; then attach a rope to the strip and haul at the windlass, whereby the rope is tightened and the blubber draws loose, the men cutting it away from the carcase with sharp spades, so that the whole envelope of blubber is removed spirally by turning the body over, and is hauled on deck.

The blubber is first placed 'tween decks, and is there cut up by machinery into smaller pieces, which are packed in casks, to be subsequently stowed in the hold. In many instances, however, it is immediately melted down on deck, in an iron pan set in brickwork, the oil being strained and filled into casks, whilst the residue (greaves) serves as fuel.

The blubber in the casks begins, after prolonged storage, to putrefy in consequence of the decomposition of the tissues and other animal matters, and a part of the oil runs out of its own accord and is collected in special recipients. When the vessel arrives at her destination the blubber still left in the barrels is melted down over a fire or by steam, and the self-run oil is also heated to about 100° C. to allow the impurities to subside. In some places the blubber, after being cut up, is melted in large pans 14 to 20 feet high, by direct steam, for five to eight hours. The carcase itself, when stripped of blubber, is either thrown back into the sea or worked up for manure.

The dorsal fat yields darker oil than the belly fat, and is treated separately. The yield ranges from 6 to 20 tons of blubber per whale.

When the work is performed in a rational manner, considerable quantities of oil, though of inferior quality, are obtained by treating the flesh and bone in the carcase with high-pressure steam, the residual portions being dried and sold as manure.

Smaller marine mammals, such as the porpoise, are disembowelled, cut into pieces, and the flesh and fat, as well as the bony skeleton, extracted by boiling over direct fire or by steam.

(*a*) *Porpoise Oil.—Brown Fish Oil* is pale yellow, brown-yellow or brown, with a smell resembling that of sardella oil, but loses this on exposure to air, and assumes a deeper shade of colour. The fresh oil is neutral to litmus paper, but absorbs oxygen from the air, and then has an acid reaction. Its specific gravity at 15° C. = 0·9220; setting-point, – 15° C. Cold alcohol dissolves 1·2 per cent.; boiling alcohol, 20 per cent. The constituents of this oil are: glycerides of physetoleic, oleic, stearic, palmitic and valeric acids.

(*b*) *Dolphin Oil.—Round-headed Dolphin Oil* is pale yellow in colour and has a strong fishy smell; specific gravity at 15° C. = 0·918; at 20° C. = 0·9175. One hundred parts of boiling alcohol of specific gravity 0·812 dissolve 40 parts of the oil, the solution becoming turbid at 50° C.; 100 parts of boiling alcohol of specific gravity 0·795 dissolve 60 parts. When exposed to low temperatures, the oil at 5° C. to – 3° C. deposits spermaceti, and when thus freed from the latter substance dissolves in equal proportions in boiling alcohol, the solution exhibiting a weak acid reaction, which disappears on the addition of water.

(*c*) *White Fish Oil.*

(*d*) *Porpoise Oil* (Tümmlerthran).

(*e*) *Narwhal Oil.*—Very pale in colour; almost white.

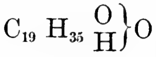
(*f*) *Sperm Oil.—Cachelot Oil,* of which a large fish will yield from 70 to 90 tons and 50 cwt. of spermaceti, is pale yellow to slightly brownish-yellow, clear, with a decidedly fishy smell and fairly fluid, with a specific gravity of 0·920 at 15° C. At 6° C. it begins to deposit spermaceti, and stearine at 8° C. Two vols. of the oil are soluble in 10 vols. of alcohol at the ordinary temperature; and 7 vols. in 10 of boiling alcohol. It is miscible with ether in all proportions, and sets slightly under the elaidin test, thus differing from all other fish oils.

One constituent of sperm fat is spermaceti oil (liquid sperm or whale oil). The alimentary canal and the bladder of this whale contain the highly-prized perfume known as ambergris.

(*g*) *Arctic Sperm or Dwarf Whale Oil.*—This product is colourless to brown, of slightly repellent smell, thin, with a specific gravity of 0·905 at 15° C.; absorbs oxygen from the air and thickens, its specific gravity at the same time increasing. It contains a relatively low proportion of solid fatty acids since it remains liquid below 5° C., with merely a slight turbidity, and only below −2° C. becomes gruelly in consistency. It dissolves in 25 parts of cold and 2½ parts of boiling alcohol, but separates out again, for the most part, on re-cooling.

When treated with nitrous acid the oil exhibits a tendency to set. It contains only about half as much oxygen as other fish oils, and consists of:—

79·87	per cent.	carbon
13·36	,,	hydrogen
6·77	,,	oxygen
100·00	,,	

and, in addition to physetoleic acid, etc., about 1 per cent. of spermaceti. Doeglic acid  $C_{19}H_{35}\left.\begin{matrix}O\\H\end{matrix}\right\}O$ is a mixture of physetoleic acid and an allied acid, as is apparent from the uneven number of carbon atoms in the formula.

(*h*) *Fin-back Whale Oil, Keporkak Oil, Rorqual Oil.*—The oil is colourless to brown, and has a specific gravity of 0·915 to 0·920 at 15° C., according to class. It deposits a little stearine at 8° C., and thickens completely at 3° C. The dark kinds have a peculiar, highly-repellent smell. With ether it is miscible in all proportions, and the darker grades manifest the remarkable faculty of mixing with equal volumes of alcohol to form a clear solution, quickly separating, however, into oil and an alcoholic solution, 10 parts of alcohol taking up 4 vols. of the oil. If now this liquid be mixed up again it remains turbid and separates into the original volumes of oil and alcohol, the latter containing a little oil and stearine. In boiling alcohol nearly 4 parts are dissolved, and 4 vols. of the oil dissolve 1 vol. of alcohol.

Fin-back oil contains:—

77·05	per cent.	carbon
12·05	,,	hydrogen
10·90	,,	oxygen
100·00	,,	

(*i*) *Greenland Whale Oil.*—The carefully prepared oil is honey-yellow in colour, and smells and tastes like fish and tar. Specific gravity at 15° C., 0·925 to 0·927; a few crystals are deposited at 10° C., which increase as the temperature falls, until, at − 2° C., nearly all the stearine and a little spermaceti are down. Five vols. of the oil dissolve 1 of alcohol, and 10 vols. of alcohol 1 of the oil, but at boiling heat 2 vols. of alcohol dissolve 5 of the oil; it is also miscible in all proportions with ether. When heated for some time at 200° C. it decomposes and blackens. Its elementary composition is:—

76·85	per cent.	carbon
11·80	,,	hydrogen
11·35	,,	oxygen
100·00	,,	

The whale oils are neutral when fresh but become faintly acid after a while, and behave similarly to seal oils under the influence of various reagents.

Fuming nitric acid produces at first a brownish coloration with a very slight tendency towards blue, turning thereafter brown, and finally blackish-brown. Sulphuric acid (specific gravity 1·65 to 1·70) colours them brown, subsequently blackish-brown (blood colour in the case of seal oils). Nitric and sulphuric acid in equal volumes give, when mixed with an equal bulk of the oil, a yellow coloration, turning reddish and subsequently a dirty brown. Caustic soda colours all fish oils red-brown, as does also syrupy phosphoric acid.

The various whale oils, all of which deposit stearine along with a little spermaceti, near the freezing-point, are further treated for the preparation of sundry commercial grades, which are principally obtained from Norway. The pure oils, *i.e.*, pale, brownish-yellow to brown, are known as "unpressed whale oil" from the method of production, and are classified according to colour. When pressed below the freezing-point, two different products are obtained—"whale fat" or "train tallow" and "pressed whale oils" containing no stearine.

2. *Seal Oils.*

Raw Material.—The blubber of the finned mammals, the walrus, seal, or sea cow, in the northern and southern oceans.

Preparation.—The carcases are brought to land and the skins removed and treated in a special manner. The blubber, which occurs as a more or less thick layer between the outer epidermis and the actual flesh, is then cut away as cleanly and carefully as possible, the entire sides thus obtained being placed in large recipients 9-11 yards long and nearly 9 yards wide, the bottoms of which are made of strong balks of timber, and the sides of wooden posts set very close together, the oil flowing out through the interstitial spaces. Below these vessels is a somewhat larger staunch wooden reservoir, only some 40 inches in height, for catching the escaping oil. Water is placed in the bottom, so that any leakage is detected without loss of oil, the water serving also to cleanse the oil from any admixture of blood. When the first-named vessel is filled with blubber up to a certain height the pressure of the mass begins to force out the oil, which then runs down into the reservoir below. The oil takes two or three months to all run out, but the product is divided by drawing off the oil at certain intervals and storing each lot in separate tanks, etc. The earliest runnings are pale, devoid of smell, and form the best quality, "light train oil," the quantity being some 10 per cent. of the total 60 to 70 per cent. of oil obtained. In proportion as putrefaction progresses with the length of storage, and the cellular texture is destroyed, the oil runs away more reddish-yellow in colour, the shade deepening continually by reason of the spontaneous and progressive heat evolved in the mass, until finally the oil is a dark-brown, and possesses a disagreeable and repellent smell and taste, arising from the decomposition products evolved. When, after a long while, the oil ceases to run of itself, the entire stinking mass is shovelled out and made up in smaller heaps, the oil thereafter escaping being collected as an inferior quality. The residue still remaining is boiled in water in large iron pans along with all the fleshy and other portions that do not contain enough oil to run out spontaneously. During the boiling the oil ascends to the surface and is skimmed off, and the residue, when dried, makes a good manure.

(*a*) *Walrus Oil.*

(*b*) *Seal Oil, Sea-dog Oil.*—In commerce there are two grades, the pale and the dark oil; it is thinner than the first seal oils, has a specific gravity of 0·9250, and does not deposit stearine until – 2° C. is reached. One hundred vols. of cold alcohol dissolve 1 vol. of the oil; hot alcohol from 10 to 12 vols.; 10 vols. of oil dissolve 1½ vols. of alcohol. The fresh oil does not give an acid reaction.

(*c*) *Archangel Seal Oil, Sea-calf Oil.*—Colour pale-yellow to brown; specific gravity at 15° C. = 0·9155 to 0·9165, the various grades having the following densities:—

Pale Archangel seal oil	at 15° C.	= 0·9165
Brown ,, ,,	,, 25° C.	= 0·9170
Sea-calf oil	,, 15° C.	= 0·9155

The product has a weak acid reaction and deposits stearine at 3° C.; 100 vols. of cold alcohol dissolve ½ vol., and hot alcohol 8 to 9 vols. of the oil, 10 vols. of the latter taking up 1½ vols. of alcohol.

(*d*) *Greenland Seal Oil.*—The commercial varieties have the following densities at 15° C.:—

Clear pale Greenland seal oil, specific gravity	= 0·919
Clear brown ,, ,, ,,	= 0·921
,, ,, ,, ,,	= 0·924
Boiled ,, ,, ,,	= 0·926

The grade known as *Greenland "Three crown" oil* is a mixture of various fish oils, principally seal and shark oil, the less important constituents being very small quantities of whale and walrus oils. The seal oil used for this product is the so-called "foots," *i.e.*, the sediment obtained in the boiling and clarifying of seal oil. This forms the chief component, the shark oil thinning down the "foots," and imparting special properties on account of its low specific gravity.

Swedish "Three crown" oil is also a mixture of various seal oils with ordinary fish oils. Both kinds are met with adulterated with fatty vegetable oils. The specific gravity of the "Three crown" oil is 0·923. The Greenland "Three crown" oil deposits stearine below 5° C. The ratios of solubility in alcohol are as follows:—

100 vols. of cold alcohol 1 vol. of oil, 100 vols. of hot alcohol 9 vols. of oil; 10 vols. of oil dissolve 1 vol. of alcohol; 10 vols. of oil require 7½ vols. of ether for their solution.

(*e*) *Newfoundland Seal Oil.*—The yellow, inodorous, darker and strong-smelling commercial varieties have densities of 0·927, 0·927 and 0·927, respectively, at 15° C. The setting-point is below 4° C., and the solubility ratios the same as the preceding class.

(*f*) *South Sea Seal Oil,* from the long-nosed seal, sea elephant, sea lion, eared seal, or New Holland seal, is pale-yellow to brown in colour and has a specific gravity of 0·921 to 0·930 at 15° C.

(*g*) *Caspian Seal Oil.*—All walrus and seal oils have a disagreeable smell, that of the brown kinds, which is due to putrefaction products, being the least supportable. They contain glue but no albuminoids; the former may be precipitated by treatment with pigments and metallic salts. The specific gravity at 15° C. ranges from 0·915 to 0·930; they are but slightly soluble in alcohol, and require almost their own volume of ether to effect their solution. A few already deposit stearine below 5° C., others set only below zero C. (at – 2° to – 3° C.) to a sold mass. When quite fresh their reaction is but faintly acid, but the percentage of acid increases with age. They contain principally glycerides of physetoleic, stearic, palmitic and (a little) oleic acid along with small quantities of butyric acid, valeric acid, etc.

Light-brown Greenland oil consists of:—

77·10	per cent.	carbon
13·50	,,	hydrogen
9·40	,,	oxygen
100·00	,,	

Fuming nitric acid gives a red-brown coloration with all seal oils. Sulphuric acid (specific gravity, 1·65-1·70) gives at first a reddish-yellow, then reddish-brown, and finally brown-red (blood-like) colour. Nitric acid and sulphuric acid—equal volumes—stain a reddish tinge at first, turning to brown and finally dark-brown.

The tests for adulteration with other oils are directed towards other fish oils and resin oils, which can be recognised on the one hand by their greater solubility in alcohol, and on the other by their incomplete saponification.

3. *Fish* (*Waste Train*) *Oils* (*Fischthrane*).

Raw Material.—Small fish, such as the herring, sprat, sardine, sardella, pilchard, menhaden, or the waste materials therefrom, and from smelt, salmon, silurus, sturgeon, etc.

Preparation.—The heads, gullets and entrails of the herring, sardine, sardella, etc., as well as the whole fish of these genera, when caught in excessive quantities and not otherwise utilisable—perhaps already in a state of putrefaction—are boiled with water in large iron pans, the fat collecting at the surface being skimmed off, clarified in large vats, and packed for sale; the residue finds employment in the manufacture of fish guano. The use of sulphuric or hydrochloric acid has been found advantageous in boiling. In another process the fish are sprinkled with 5 per cent. (by weight) of a 45° Bé. solution of ferric chloride or ferric sulphate, which preserves them unaltered for four or five days; they are then beaten to a pulp, and pressed, by which means a large quantity of water and oil is forced out. The press-cakes are easily dried, becoming friable and pulverulent, and can be pressed a second time between hot plates, or extracted with volatile solvents, whereby a further quantity of oil can be recovered. Oil can also be obtained from such fish and fish waste by means of the centrifugal separator (German Patent, No. 23,974).

(*a*) *Herring oil, Swedish fish oil, Russian fish oil, Astrachan herring oil ;*

(*b*) *Sprat oil ;*

(*c*) *Sardine oil, Italian fish oil, Mediterranean fish oil ;*

(*d*) *Pilchard oil, Spanish fish oil ;*

(*e*) *Sardella oil ;*

(*f*) *Menhaden oil ;*

(*g*) *Salmon oil.*

These fish oils have a specific fishy taste and smell, and are pale yellow to brown in colour, with a specific gravity of 0·925 to 0·930 at 15° C. Near freezing-point they deposit stearine. Alcohol takes up only 2 per cent. of the oil in the cold and 3·5 per cent. in the warm, and 5 vols. of oil require 2 vols. of ether for their solution. All (waste) fish oils are browned by fuming nitric acid. Sulphuric acid of specific gravity 1·65 to 1·70 imparts a characteristic greenish coloration at first, turning to brown, and finally quite black. Sulphuric and nitric acid in equal volumes, mixed, produce at first a yellowish, then greenish, and subsequently brown coloration.

4. *Liver Oils* (*Leberthrane*).

Raw Material.—The livers of the following fish: Cod, ling, haddock, coal fish, merlangus, pollack, sea-pike, or small cod, shark (common shark, great shark, ice shark, hammer-headed shark), ray (prickly ray, smooth ray, spiny ray).

Preparation.—The process of preparation is not every-where alike, and is carried out with greater or less care, so that, naturally, the products differ both in point of colour, taste and smell.

1. After the catch the liver is cut out of the fish, collected, cleansed of blood and adherent entrails, and placed in high upright casks fitted with three taps at the side and exposed to the sun. By this heat, and that developed spontaneously in the mass, a liquid is obtained resembling poppy oil, and known as "clear pale liver oil". This product is drawn off through the two upper taps, and the contents of the cask are then weighted with stones. The oil obtained from longer stored liver is never so clear and well-flavoured as that from fresh. In the course of further spontaneous heating and the concurrent putrefaction a further quantity of oil, known as "clear brown liver oil" is obtained, and is drawn off through the bottom tap. The residue in the cask is boiled or roasted in iron pans and yields "brown liver oil".

2. By steaming the liver—a method calculated to advantageously replace the putrefaction process—finer and more limpid oils of milder flavour and almost neutral reaction are obtained, whereas the self-run oils are always more or less decidedly acid. In the steaming process, the well-cleaned livers freed from blood and cut up small are treated with a little steam in closed vessels, whereby the tissues contract and the oil runs out. The product thus obtained is "medicinal (liver) oil" or "steam liver oil," and being mainly prepared at Bergen in Norway, is met with in commerce as "Bergen liver oil". In the same way also "Newfoundland" and "Labrador liver oils" are prepared, these differing from the first-named only by a somewhat larger content of stearine, which begins to deposit at 7° to 5° C. The residues from the steaming process are pressed and yield a second, rather more highly-coloured oil. In the preparation of liver oil by steam the following points have to be observed :—

(1) Great care must be exercised in the selection of the liver, only perfectly sound livers—but not green, reddish or blackish pieces—being chosen, since the coloured kinds specified are only fit for tanners' oil. Liver that has lain for more than twelve hours in summer or twenty-four hours in winter is no longer suitable for medicinal oil.

(2) Excessive cleanliness must prevail, and both the liver and the vessels must be cleansed with hot water every time.

(3) The liver must not be heated above 70° C. nor exposed to that temperature for more than forty-five minutes; the shorter the better.

(4) Filtration must be very carefully performed in order to remove even the very finest solid particles from the oil. During the entire process the oil must not be exposed to the air any more than is absolutely necessary.

(5) Pressing is a method employed chiefly in Scotland. The fresh liver, thoroughly cleaned and cut up small, is heated in iron pans to 80°-90° C., and continually stirred until converted into a pulpy mass, which is then placed in large calico bags, filtered whilst hot, and the residue pressed in bags. At 15°-16° C. the oil deposits a considerable quantity of stearine, which is removed by filtering. The well-cleaned and perfectly fresh livers are also heated along with water to 80° C. until all the oil has run out, the latter being skimmed off and filtered through flannel—a second filtration following in order to remove the solid matters deposited during the interim.

(*a*) *Liver Oil.*—Cod-liver oil (Kabljauthran, Dorschleberthran, Stockfischleberthran).

The commercial varieties are :—

(*a*) *Clear Pale Liver Oil.*—Colour, golden yellow; smell characteristic, not disagreeable; flavour fishy, not bitter; reaction, faintly acid to litmus paper; specific gravity, 0·923 at 15° C.; solubility, 2·5-2·7 per cent. in cold, 3·5-4·2 per cent. in hot alcohol.

(β) *Clear Brown Liver Oil.*—Colour, chestnut brown; smell and taste, strong, bitter and irritating to the throat; reaction, more strongly acid to litmus paper; specific gravity, 0·925 at 15° C.; solubility, 2·5-3 per cent. in cold, 5-6 per cent. in hot alcohol.

(γ) *Brown Liver Oil.*—Dark brown, occasionally blackish brown in colour, greenish to bluish green by transmitted light, transparent in thin layers; peculiar, unpleasant, empyreumatic odour and bitter taste, highly irritating to the throat. The oil strongly reddens litmus paper, and has a specific gravity of 0·929 at 15° C. Alcohol dissolves 5·7-6·5 per cent. in the cold and 6·5-7 per cent. at boiling temperature; ether dissolves it in all proportions.

Properties of Cod-liver Oil.—These, so far as regards colour, smell, taste and solubility, have been already detailed. The elementary composition is as follows:—

75·91	per cent.	carbon
12·22	,,	hydrogen
11·87	,,	oxygen
100·00	,,	

Liver oils are mixtures of numerous glycerides: those of oleic, physetoleic, stearic and myristic acids; and, moreover, contain free acids such as butyric, acetic, gallic acids, and gall constituents such as fellic acid, cholic acid, bilisalic acid, biliverdin, bilisulom. Among the bases present are small quantities of trimethylamine, propylamine, amylamine, hexylamine and a new base, hydrotoluidine, boiling at 198° to 200° C., as well as two non-volatile bases, aselline and morrhine (yellow oil 2·5-3 per cent.; white oil 1·5-2 per cent.; brown oil 4·5-6 per cent. of morrhine).

There are likewise present, in organic combination, small quantities of chlorine, bromine, iodine, sulpho-phosphoric compounds, along with sulphatic and phosphatic salts of lime, magnesia and soda.

(*b*) *Coal-fish Oil* (Saythran, Sayleberthran, Kohlfischthran).

These oils correspond in flavour and smell with cod-liver oil. Cold alcohol dissolves 3·4 per cent., hot alcohol 6·5 per cent. The chemical composition agrees with the foregoing oil. Coal-fish oil exhibits the peculiarity of depositing solid fatty acids at 5° to 10° C., of which it contains, according to the researches of Kremel, twice as large a quantity as cod-liver oil; although it should not be forgotten that their amount depends on the more or less careful removal of the stearine during the preparation of the oil. The specific gravity is 0·925-0·927 at 15° C.

(*c*) *Shark's-liver Oil* (Haifischthran).—The liver of the shark is very heavy, often weighing as much as 1 ton (giant shark) and yielding some 5 cwt. of oil.

The colour of the oil is pale yellow and clear, and it still remains liquid when cooled to 6° C.; its specific gravity is 0·870-0·875, or at most 0·880, at 15° C., a shark's-liver oil with a higher specific gravity than this being always regarded with suspicion. The smell is peculiar, but not very repellent, like the taste, which produces an irritating after-effect. Ten vols. of cold alcohol dissolve 1 vol., hot alcohol 4 vols.; 1 vol. of ether, 1 vol. of oil. The oil burns with a bright flame without carbonising the wick. The constituents are the same as in cod-liver oil, but in different proportion; the amount of iodine is somewhat larger.

(*d*) *Ray-liver Oil* (Rochenleberthran).—Colour pale or golden yellow; taste and smell less unpleasant than in ordinary liver oil; there is no acid reaction; specific gravity at 15° C., 0·928; cold alcohol dissolves 1·5 per cent., hot alcohol 14·5 per cent., cold ether $\frac{1}{2}$ vol., boiling ether 88 per cent. Near the freezing-point it deposits stearine; and it contains a larger percentage of iodine than cod-liver oil. Chlorine gas produces scarcely any alteration.

According to Benedikt, cod-liver oil is a highly complex mixture of small quantities of olein, physetolein, palmitin, stearine, etc., with the glyceride of a hitherto unknown fatty acid, probably belonging to the linolic acid series. It contains variable amounts of free fatty acids, for the saturation of which Kremel found 0·62 to 28·67 grams of calcium hydrate necessary per 1000 grams of oil. A little cholesterin (0·46 to 1·32 per cent. according to Allen and Thomson) is present and can be recovered by saponification and extraction with ether, the characteristic tabular crystals of cholesterin being obtained by recrystallising from alcohol the residue left after evaporating the ether. On the other hand, according to Jean, 6 per cent. of liver oil consists of a pale yellow, oily, unsaponifiable mass, which is stained a beautiful red by the addition of one drop of sulphuric acid.

Characteristic of this oil is its content of bile constituents, by reason of which several colour reactions can be obtained. The ash contains iodine, which can best be detected by saponifying the oil with caustic potash or soda, concentrating, calcining the residue, and then testing for iodine in the ordinary manner. None of the iodine can be extracted by shaking up with water or alcohol, so that the intentional addition of potassium iodide to this oil can be detected by extracting with alcohol and testing the residue left on evaporating the solvent. Kremel made the examination of liver oils the subject of exhaustive study, principally with the object of finding characteristic indications for distinguishing cod-liver oil, Japanese oil, coal-fish oil and seal oil.

As will be seen from the appended table, no reliable information can be obtained from the specific gravity, iodine number or saponification value. On the other hand, coal-fish oil contains twice as large a quantity of solid fatty acids as do any of the other fish oils, which, however, may, as already mentioned, proceed from a careless separation of the stearine.

Oil.	Specific Gravity.	Percentage of Liquid Fatty Acids.	Percentage of Solid Fatty Acids.	Melting-point of the Fatty Acids. ° C.	Acid Number.	Saponification Value.	Iodine Number.
1. Cod-liver oil, 1884	0·922 to 0·927	—	—	—	0·62	171	131
2. ,, 1883		92·12	6·72	—	1·41	171	127
3.		—	—	—	2·06	—	126
4.		88·88	7·55	50·5	2·23	189	127
5.		—	—	—	2·32	—	128
6.		90·46	6·88	51	2·86	179	131
7. ,, 5 years old		—	—	—	1·47	178	140
8. ,, 10 ,,		—	—	—	28·67	—	—
9. ,, 10 ,,		—	—	—	5·03	—	129
10. Clear pale medicinal liver oil		—	9·60	48-49	9·59	173	139
11.		—	—	—	11·29	174	138
12.		—	—	—	11·57	173	141
13. Cod-liver oils from 1883 and 1884		92·72	5·25	52	8·66	181	—
14.		87·00	12·75	51-52	6·78	181	135
15.		—	—	—	10·46	—	136
16. Coal-fish oils, 1883	0·925	75·32	19·04	55-56	1·26	177	137
17.	0·926	—	12·22	53	1·23	177	137
18.	—	—	—	—	1·29	179	129
19.	0·925	74·20	20·60	—	1·49	181	126
20.	0·927	70·00	21·34	52	1·68	181	123
21. Japanese liver oil	0·908	87·60	10·52	50-51	—	—	120
22. Seal oils, 1883	0·925	85·20	10·23	57·5	1·95	178	127
23.	0·925	88·29	9·80	57	2·01	179	128

The melting-point of the solid fatty acids is higher in seal oil than in the other kinds.

According to Mayer, a liver oil is pure if, when shaken up with one-tenth of its bulk of nitro-sulphuric acid (1 : 1), it gives a coloration bright red at first but quickly turning to citron yellow, since in the other fish oils the transition is either not so clean or else a brownish-violet coloration is produced.

Rössler agitates with aqua regia, with which pure cod-liver oil forms a greenish dark-yellow liniment, turning a permanent brown after half an hour, whereas white seal oil or a mixture thereof with cod-liver oil gives a faintly yellow liquid under this test.

Kremel found the behaviour of the oil in presence of fuming nitric acid (specific gravity 1·50) a far more suitable means of identification. If 10 or 12 drops of the sample be placed on a watch glass and 3 to 5 drops of nitric acid run in from one side, the following changes are observed :—

Pure cod-liver oil becomes red at the plane of contact of the liquids, turning to bright red on stirring, but quickly changing into a pure yellow.

Coal-fish oil becomes intensely blue at the point of influx, the colour changing to brown on stirring, and remaining so for two or three hours, to finally become black.

Japanese fish oil behaves like the last named except that red streaks often accompany the blue.

Seal oil is unaltered at first, and turns brown only after some time.

The nitric acid reaction is so characteristic that the adulterations named can be detected easily in quantities from 25 per cent. downwards.

The adulteration of the oil with non-drying fatty oils can be detected by the iodine number, which is in these fish oils unusually high.

Drying oils may be recognised by spreading a sample out thinly on the surface of a glass plate, in that the fish oils, although they oxidise very quickly, form no solid skin.

If 1 part of fish oil be stirred up thoroughly with 2 parts of concentrated sulphuric acid in a tall glass, the mixture will be clear only in case no foreign fats are present.

Testing Fish Oils.—The better classes of fish oils are for the most part only adulterated with similar oils of low quality, falsification with other oils being practised on the medicinal oils only. In testing, regard must be paid to the specific gravity. Shark oil is the lightest, the specific gravity being 0·870 to 0·875 at 15° C.; next follow the whale (blubber) oils, 0·9100 to 0·925; the seal oils, 0·915 to 0·930; the liver oils, 0·920 to 0·950; and the fish (waste) oils, 0·925 to 0·930. These particulars refer only to the pale and clear brown oils, the darker sorts averaging about 0·005 more. A further guide to a decision is afforded by the varying solubility in alcohol.

Seal and whale oils are very readily soluble (the former up to 15 per cent.) in hot alcohol, so that more than 1 vol. of oil dissolves in 1 vol. of alcohol, whereas liver oils dissolve only up to 6 or 7 per cent., and fish (waste) oils only to 4 per cent. By solution in alcohol the presence of resin and mineral oils can be detected at the same time (being characterised by their ready solubility in alcohol), but they require, however, to be confirmed by the saponification test, being themselves unsaponifiable. The addition of resin may also be proved by agitation in cold alcohol.

For the identification of pure cod-liver oil, 10 parts of oil must, according to Mayer, be shaken up with one part of a mixture (1 : 1) of sulphuric and nitric acids, in a stoppered flask, whereupon pure cod-liver oil becomes a brilliant red, quickly changing to citron yellow, whilst other fish oils do not exhibit the transition into yellow so cleanly, but become more of a brownish violet. On agitating fish oil with concentrated aqua regia, a greenish dark yellow liniment forms in the case of pure cod-liver oil, which changes in half an hour to a persistent brown, whereas white seal oil or a mixture of same with pure oil forms merely a pale yellow, faintly tinged mixture. The behaviour of the various grades in presence of fuming nitric acid of specific gravity 1·50 affords a better means for their identification. If 10 to 15 drops of the oil to be tested be placed on a watch glass, and 3 to 5 drops of the fuming acid be run in from the one side, the various fish oils behave as follows:—

Pure cod-liver oil turns red at the place of contact, the colour becoming a brilliant red on stirring up with a glass rod, but changing in a short time to pure citron yellow.

Coal-fish oil becomes an intense blue at the point of contact (as in the reaction of biliary colouring matter with concentrated sulphuric acid), changing to brown when stirred. This coloration persists for two or three hours, to finally pass over into a more or less pure yellow.

Japanese fish oil behaves similarly, but oftentimes the blue coloration is accompanied by red streaks.

Seal oil gives no colour reaction at the outset, and is coloured brown only after some time.

According to Salkowsky, the adulteration of liver oils with vegetable oils can be recognised by the following methods:—

The Setting-Point and Melting-Point.—The first of these is fairly low in fish oils, but the individual kinds vary considerably among themselves, owing to the removal of the solid portions in some by cooling. The time of the operation is also of importance, it being feasible in a few cases only, *viz.*, palm oil, cocoanut oil, palm-kernel oil, when something like 20 per cent. is present, to detect them by the rapid setting of the liver oil.

The Reichert-Meissl number was found for liver oils after deduction of the correction 0·2 (0·1 to 0·2 for the indicator per 5 grams). For the majority of the fatty oils few higher numbers were obtained; only for cocoanut oil and palm-kernel oil were the numbers 7·38 and 3·48 found. Only these two oils would therefore be detectable with any degree of probability in fish oil, and then only when in large quantity.

Estimation of the phytosterin content. The test is preferably applied in two forms, in that on the one hand sulphuric acid is run direct into the oil in a watch glass, and, on the other, a few drops of the oil are dissolved in chloroform and then shaken up with the acid. A blue coloration ensues, the cause being attributable, not to the 0·3 per cent. of cholesterin, nor to any biliary colouring matter present, but rather to a pigment known as lipochrome.

The cholesterin of liver oil is not identical with that obtained from vegetable oils, the latter agreeing with phytosterin. Cholesterin sets to a pulp of laminated crystals, phytosterin to fascicular groups of solid needles. The melting-point of the latter is about 132° to 134° C., that of cholesterin being 146° C. These differences are sufficiently characteristic to enable vegetable fats to be detected in liver oil. If 10 grams of liver oil be saponified with 10 grams of caustic potash and a little alcohol, then diluted with water to a 600-700 c.c. solution, shaken up with 500 c.c. of ether, and the ethereal extract filtered, evaporated and purified, if necessary, by a second saponification, the cholesterin will be obtained in a nearly pure state. That from pure liver oil will have a melting-point of 146° C., whilst that from oil containing 20 per cent. of vegetable oils will melt at 139°-140° C.

The microscopical examination of the cholesterin affords another means of detecting adulteration. The percentage of free fatty acids in good liver oils is very small, about 0·25 to 0·69 per cent., whilst most of the commercial vegetable oils contain larger quantities.

The method proposed by Salkowsky for estimating the volatile fatty acids insoluble in water is rather cumbrous and uncertain in its results and is therefore not very suitable for use in practice.

Whereas liver oil contains, according to Allen and Thomson, 0·46 to 1·32 per cent., or, according to Salkowsky, only 0·3 per cent. of cholesterin, Jean found therein 6 per cent. of an oily, unsaponifiable substance, which gives a beautiful red coloration with a drop of sulphuric acid. In order to test the accuracy of these reports Fahrion determined the cholesterin in thirty samples of fish oils, by Hönig and Spitz's method. Of these, fourteen contained less than 1 per cent., eleven between 1 and 2 per cent., three between 2 and 3 per cent., and only two shark oils more than 3 per cent. of unsaponifiable matter. Shark oils are classed on the one hand with the liquid waxes, and on the other with the liver oils, the numbers obtained speaking more in favour of the latter assumption.

In the case of cod-liver oils the darker sorts, as a rule, contain more cholesterin than the lighter grades. This may result from the method of preparation, the lighter qualities being obtained by cold, and the darker by the subsequent warm pressing. From the figures obtained it is permissible to conclude that the cholesterin content (6 per cent.) reported by Jean is quite possible.

Dulière examined various liver oils and found the values given in the French Pharmacopœia to be too low; there the specific gravity is given as 0·920-0·922, whereas he found it to be 0·9271 at 15° C. Oil prepared from fresh livers should not redden blue litmus paper. Contrary to the views of various investigators, Dulière was unable to discover any alkaloids in perfectly fresh liver oils or in the white commercial oils. The iodine numbers of liver oils freshly prepared by the author, as well as those of good commercial grades, approximate very closely, and range from 144 to 151; the Indian and similar oils have iodine numbers varying between 116 and 138·74, and that of Japanese oil is still lower, *viz.*, 98·74. According to Dulière the saponification value of a good liver oil is between 19·48 and 21·61.

ARTIFICIAL TRAIN OIL AND ITS PREPARATION.

By artificial train oil is understood a dark-coloured product prepared from resin oil and extensively circulated in commerce under the name of "lion train oil" (Löwenthran). It plays an important part in chemical industries on the small scale. The pale train oils, commercially known as fish oils are as a rule pure, or at most adulterated, being rarely exclusively artificial products.

The dark oil is, as already mentioned, chiefly a resin product. Although low quality materials alone are used for its production, the preparation is particularly difficult owing to the very particular requirements exacted by consumers. The criteria of the quality of artificial train oil are colour, smell, viscosity, and feel, as well, of course, as deceptive appearance, it being necessary for the colour to be deep black, without fluorescence, by reflected light and reddish brown in thin layers by transmitted light. The oil must be perfectly clear and of at least the consistency of syrup. When rubbed between the fingers it should not exhibit any great degree of slipperiness, although not sticky, such as happens when, *e.g.*, Vulcan oil is present.

It is a decidedly difficult matter to produce from the materials at disposal (in Germany) an artificial train oil that can fulfil the above requirements and be sold at the low prices brought about by foreign competition.

The chief material employed is the so-called resin stock oil, which in correspondence with the properties of the product, should be very thick and have the least possible smell and bloom. The paler and clearer the stock oil the better it is adapted for the purpose in view, a turbid and consequently darker resin oil being much less suitable.

The next constituent in point of importance is "blue oil," the quality of which is an even more particular matter than that of the resin oil. The specially strong smell and fluorescence characteristic of Galician "blue oil" are generally so difficult to remove or mask, that here already the fundamental causes of bad quality in the final product are to be sought.

Unimportant as raw materials are the nitric acid and molasses, by means of which nearly all "lion train oils" are prepared. 2 parts of resin oil are mixed with 1 part of "blue oil" (the proportions are varied according to the degree of viscosity desired), a fairly concentrated nitric acid being then added which de-blooms the mixture probably by the formation of nitro compounds from the hydrocarbons of the resin oil, and moreover deodorises and darkens the product, 1·5 to 2 per cent. of acid being sufficient to effect these objects so far as is possible with these raw materials. The smell of resin oil in particular does not entirely vanish, but this does not matter much, as in the finished product it will resemble train oil. The addition of 2-4 per cent. of molasses helps both the colour, and more particularly the masking of the smell. During the entire process the temperature in the pan (open pan heated by direct fire) is kept at about 60°-80° C. As soon as the product exhibits the desired appearance it is left to stand for two or three days to clarify completely.

In the manufacture of leather grease, a large quantity of a liquid oil is recovered as well as the solid fat, and may be classed as "extracted train oil". This dark oil, which has a decided fish-oil smell and the properties of good natural fish oil, has given excellent results as an adjunct to artificial train oil, an addition of 5 per cent. of this leather train oil to a comparatively poor "lion train oil" having effected such an improvement in the latter that a dealer, who from long experience may be considered as an expert, and before whom samples of the original "lion" oil and the same after addition of the leather oil were placed for an opinion, classed the latter as good and the former as unfit for use.

In preparing light-coloured train oil the *modus operandi* is as follows:—

Good, pale, bloomless, faint-smelling resin oil is mixed with $\frac{1}{3}$ to $\frac{1}{2}$ (according to the viscosity, etc., desired) of debloomed Russian oil of specific gravity 0·885 (or Galician oil of specific gravity 0·895-0·905) and warmed. When cold, 5-10 per cent. of pure fish oil is mixed in, together with a trace of trimethylamine solution, and well stirred. Should turbidity arise on account of the small quantity of water in the trimethylamine solution, which at most amounts to $\frac{1}{10}$ per cent., the oil is left to clarify. The product will resemble pure fish oil in all particulars, and although possessing a bitter taste, may be used with advantage as an adjunct to pure fish oil.

DÉGRAS, TANNER'S GREASE, LEATHER GREASE, WASTE GREASE (GERBERFETT, LEDERFETT, ABFALLFETT).

The substance indicated by the above names was originally a waste product obtained in the preparation of chamois (shamoy) leather, whereas it is now prepared on its own account. Formerly the price was high by reason of the article being a bye-product prepared in a special manner and only in limited quantity; and even now that dégras can be prepared in any desired amount, it is saleable at relatively high rates, a circumstance rendering its production a profitable undertaking. In composition, dégras is nothing more or less than an emulsified fat, *i.e.*, a fat existing in an extremely fine state of division in a suitable liquid, so that it forms a mass of buttery or salve-like consistency. The skins to be dressed for chamois leather are unhaired by liming and scraping with knives, and then immersed in a bath of bran in a state of acid fermentation. They are afterwards wrung out, dressed over with train oil or liver oil, fulled for two or three hours and left exposed to the air a short time. These operations of fulling with fish oil and hanging out are repeated until the skin is full of oil and all the water has been expelled, the oil having meanwhile, under the influence of the air, become partly oxidised and intimately combined with the fibre. To complete this conversion, the skins, which are laid one above another, are subjected to a kind of fermentation, air being admitted from time to time in order to prevent over-heating. The excess of oil is then removed by wringing, scraping, straking, or hydraulic pressing ; and the skins finally treated with a lukewarm solution of potash from which further portions of the oil separate out on standing. According to another account the suitably prepared skins are sprinkled with fish oil and thrown into heaps which become fairly hot in consequence of the incipient decomposition of the fat ; after a short time the skins are well fulled and finally treated with a 10 per cent. solution of potash, in which manner is formed the so-called white liquor, wherein the dégras, *i.e.*, the fat, is present as very finely divided drops. To this liquor is added enough sulphuric acid to neutralise the potash, and when the liquid is left at rest the fat collects at the surface and forms a dirty white, or yellow to brown, mass of fairly mild flavour, principally used for softening tanned leather, which substance absorbs it with great facility.

In many factories hides are used for the sole purpose of manufacturing dégras, being shamoyed again and again by alternate oiling, fermenting, fulling, and treating with potash solution until they are worn to tatters.

Various artificial products with the same name are used to replace true dégras, and are prepared from fish oils and other fats, to which are frequently added tallow, resin, oleic acid, etc., etc.

All kinds of dégras contain large quantities (mostly 12 to 20 per cent.) of water, which, in good qualities, should not separate out even after long standing. The emulsive capacity depends on the amount of a resinous oxidation product formed in the process. The larger the quantity of this substance present the more easily is the emulsion produced, so that a dégras containing 13·9 per cent. of resin substance and 53 per cent. of water produces such an intimate mixture that it will remain perfectly homogeneous even after two months.

The colour of this resin-like substance is brown, and its melting-point between 65° and 67° C. It is saponifiable, cannot be precipitated by common salt from alkaline solution (distinction from fats), is insoluble in water, soluble in alcohol and ether, but insoluble in petroleum spirit (distinction from resin). It does not occur in fish oils, but is only formed in the process of shamoying. Most kinds of dégras contain unsaponifiable substances derived from the fish oil; thus, for example, dégras from sperm oil contains cetyl alcohol, and that from liver oil an oily, unsaponifiable mass, of which 6 per cent. is present in the unaltered liver oil. The content of free fatty acids varies greatly, but the quantity does not affect the quality of the dégras. Pure dégras is contaminated with solid organic matters, particles of skin and membrane, which should, however, not exceed 5 per cent. The specific gravity of dégras, freed from water, *viz.*, 0·945 to 0·955, is higher than that of the fish oil used in its preparation.

An examination of fish oils, after Livache, by treatment with metallic lead, showed (in harmony with practical experience) that the fish oils best suited for the production of dégras are those most capable of absorbing oxygen. Whale oil is the most in demand, and sardine oil, which yields only some 3 to 4 per cent. of resinous matter, is unsuitable.

Examination of Dégras.

Water Determination.—Five grams of substance are diluted with petroleum spirit and filtered through a tared dry tube containing a wad of cotton wool, the filtrate being distilled off and the residue evaporated in a basin, dried at 120° C., and weighed. The insoluble portion is estimated by drying the filtering tube at 120° C. and weighing, the contents being then incinerated in a platinum crucible. If the residue be but small there is nothing but organic matter present, whereas if large it must be weighed and qualitatively examined (for clay, chalk, gypsum, etc.).

Ash.—For this estimation 5 grams are used. If the ash be alkaline, then it is extracted with water, filtered and titrated.

Mineral Acids.—If the dégras have a strongly acid reaction, 25 c.c. of the sample are boiled with 200 c.c. of water, left to cool, and the two layers separated by means of the separating funnel, the nature of the acid (mostly sulphuric acid) being ascertained from one part of the aqueous layer, and another aliquot part (50 c.c.) being titrated with caustic soda.

The subjoined tests are performed on the dégras after drying and filtering through linen.

Unsaponifiable Matter.—A preliminary test by boiling with alcoholic caustic potash and decomposition with ammonia readily shows whether any unsaponifiable matters are present. If turbidity occurs the test is positive, and the examination is then commenced by the quantitative determination of the unsaponifiable matters, their investigation being subsequently carried on according to known rules.

Resinous Matter.—The ether-extracted soap solution used in the foregoing determination is evaporated until the solvent is expelled, and precipitated hot with an excess of pure sodium chloride. When cooled the coloured liquid is filtered from the deposited soap into a flask and qualified with hydrochloric acid, whereupon the resin comes down in flakes, which unite on boiling and attach themselves to the walls of the vessel. After leaving to cool, the mass is brought into condition for weighing by agitation with ether, evaporation of the solvent and drying. Admixed resin is detected by extraction with petroleum spirit, which does not dissolve the resinous matter of dégras.

Extraneous Fats.—The presence of extraneous fats, such as wool fat, oleic acid, tallow, etc., may be suspected when the specific gravity of the oil extracted from dégras falls below 0·920, since dégras from fish and whale oils has a density of 0·949 to 0·955. For the presence of tallow, characteristic information is afforded by the melting-point of the fatty acids, those of tallow melting only above 40° C., and therefore raising the melting-point of those in the dégras, since the acids from whale oil melt at 24·9° C., those from liver oil at 18·5° C., and those from Japanese oil at 30·8° C.

Free Fatty Acids.—These are titrated by caustic soda and phenolphthalein. The saponification value 159 is used as a basis for calculating the percentage of free fatty acids in whale oil. The oil from dégras contains generally 15 to 19 per cent. of free fatty acids.

Jean gives the following examples illustrating the constitution of dégras :—

	1.	2.	3.	4.	5.
Water - - - - - -	18·9	19·84	12·93	28·9	19·20
Ash - - - - - -	0·25	0·13	0·55	0·7	0·07
Particles of skin - - -	0·30	0·30	0·04	0·58	0·27
Oil - - - - - -	69·71	74·65	80·00	66·93	75·66
Unsaponifiable matter - -	0·84	6·05	—	—	—
Resinous matter - - -	4·00	4·05	5·81	3·52	4·80

Fahrion, on the basis of numerous experiments, comes to the conclusion that the same products are obtained from fish oil by shamoying as are yielded by oxidation in the air, and that the dégras expressed from shamoyed leather is nothing more than a partly oxidised fish oil mixed with larger or smaller quantities of nitrogenous matter extracted from the skin. Leinand's "dégras-former" is a mixture of oxyjecoric acids and their anhydrides, contaminated by small quantities of nitrogenous substances.

When dégras was introduced as an emollient into the tanning industry its use was found to be attended by so many advantages that the waste product of the shamoying process soon became insufficient to cope with the demand. In this extremity recourse was had to fulling not only raw skins, but also the finished chamois leather, with fish oil, exposing it to the air, and when sufficiently oxidised recovering the oil by pressure as in the original process. Notwithstanding that the resulting product is identical as regards both appearance and action with the actual primary dégras (*première torse*), specially valuable properties are, in some quarters, still attributed to the latter. Against this view it must be emphatically asserted that, in general, the secondary products are preferable in so far that the fish oil extracts from the raw sheepskins the natural fat, rich in cholesterin, occurring therein, and at the same time takes up a great deal more of the nitrogenous constituents than in the case of the shamoyed leather. Fahrion prepared a similar product on a small scale by impregnating pieces of chamois leather with the sardine oil frequently employed, and, after three days' exposure to the air, extracting with ether. The "moëllon" thus prepared forms, when freed from water, a thick red oil. The analytical results obtained therefrom are subjoined, the figures for the original oil being added for the sake of comparison :—

	Fish oil in per cent.	Moëllon in per cent.
Iodine number	193·2	75·4
Acid number	20·6	29·6
Unsaponifiable matter	0·6	1·0
Fatty acids	94·5	65·8
Total oxy-acids	0·7	23·0
Solid oxy-acids	0·2	7·3

The chamois leather has the same appearance after extraction as before, its only task in the dégras process being to finely divide the particles of oil and so render it more accessible to the influence of atmospheric oxygen.

From the sum of the unoxidised and oxyfatty acids the presence of volatile matters in moëllon is revealed; and since these are evolved by prolonged heating to 120° C., and since, moreover, oxidation and condensation processes still go on at that temperature, the method of estimating moisture proposed by Jean (mixing with quartz sand and drying at 120° C.) must, therefore, be totally rejected. Drying may be continued all day long without the weight becoming constant, and almost any desired result may be obtained. Fahrion sums up the results of his thoroughgoing researches on the fish oils as follows: The by far most predominant solid fatty acid in fish oils is palmitic acid. Of liquid fatty acids they do not contain any of the known members—oleic, linolic, linolenic, isolinolenic acids—but, on the other hand, a hitherto unknown heptadecylic acid, asellic acid ($C_{17}H_{32}O_2$), and also—as a characteristic constituent which is the cause of their ready oxidation—the isomer of linolenic acid, jecoric acid, $C_{18}H_{30}O_2$. Very probably there are also one or more unsaturated fatty acids present; for example, the fact that in the combustion of oxyjecoric acid an excess of hydrogen is always obtained indicates the probable presence of a fatty acid isomeric with linolic acid. Nevertheless, since these other fatty acids do not conform to Hazura's law, nothing definite can be stated on the subject until further methods of investigation are discovered.

PREPARATION OF DÉGRAS FROM FISH OIL.

A good deal of dégras is prepared by a not very complex method, fish oil being converted into an emulsion in the following manner :—

A 10 to 20 per cent. solution of potash is heated to boiling in a roomy pan, and fish oil is run into the hot liquid in a thin stream, from a vessel situated at a higher level, the two being kept continually in motion by means of a stirring apparatus. The quantity of oil employed must be determined for the various kinds of fish oil in every case; many kinds may be used up to 50 per cent. of the weight of potash solution, whilst with others the supply must be cut off much sooner. When all the oil has been added the paddles are kept at work for some time longer, and the mass is continuously heated, samples being taken from time to time, until, after prolonged standing in a high test-glass, the milky, and apparently homogeneous, liquid does not separate into two layers, but only becomes thicker on cooling, whereupon the operation is considered at an end. The dégras is allowed to cool, but still kept stirred, incessantly, until it begins to thicken, when it is at once poured into the packages in which it is sent out for sale.

In the majority of instances the operation thus performed is conducted to a successful issue, a dégras conforming to all requirements being obtained. With some oils, however, all the trouble taken to ensure a usable product seems wasted. For example, the stuff may be heated and stirred, hour after hour, and the product will still, on standing, allow a great portion of the fat to separate out again, a circumstance leading to the conclusion that some kinds of fish oil are incapable of forming an emulsion with potash solution. On this account it is always advisable to subject oils intended for dégras to a preliminary examination for their behaviour in this connection; the test can be performed in an enamelled vessel with a few quarts of potash solution.

Fish oils that will not properly emulsify with potash lye can, nevertheless, be easily worked up into dégras by first boiling a very weak solution of caustic soda in the pan, then stirring the oil in until the liquid is milky and adding a highly concentrated solution of potash, stirring incessantly until no more drops of fat can be discerned in the mass; the above-named test is then performed. The operation is conducted as follows: In a pan of suitable size, solid caustic soda at the rate of 1 kilo (2·2 lbs.) per 100 litres (22 galls.) (26.4 American gal of water is dissolved. Two vessels, one containing the fish oil, the other the concentrated potash solution, and both fitted with taps, are placed above the pan. The potash solution is prepared by suffusing the potash with its own weight of water and leaving them to stand, with occasional stirring, for twenty-four hours, at the expiration of which time the concentrated liquor is poured off from the undissolved portion and placed in the vessel referred to.

The soda lye is first heated to boiling and the tap of the oil vessel then opened wide enough to allow a stream of the oil, of the thickness of a lead pencil, to flow, the liquid in the pan being meanwhile stirred with vigour. When the liquid has become milky after all the oil is in, the potash solution also is admitted in a thin stream, and the whole stirred until the sample shows a favourable result.

If the finished product is desired to have a thick, salve-like consistency, a somewhat larger quantity of caustic soda must be taken at the outset and the solution made of 1½ to 2 per cent. instead of 1 per cent. strength, the amount necessary being carefully ascertained by a preliminary experiment, since an excess of soda will make the cooled product more like soap than salve. The dégras should be of such a consistency that it can be easily rubbed on to the leather by the finger and as readily absorbed.

DÉGRAS ACCORDING TO HERRBURGER.

The methods of preparation are:—

(1) 50 kilos of raw linseed oil, 125 kilos of fuller's grease (previously left to stand for four or five days over spent pine tan), 25 kilos of ordinary fish oil, 16 kilos of soft (potash) soap and 1 kilo of lime soap, perfumed with $\frac{1}{100}$ part of oil of valerian and $\frac{1}{4}$ per cent. of butyric acid.

(2) A mixture is prepared from fish oil, a fish oil soap boiled with lime, and 100-120 per cent. of water, by shaking together until the mass sets.

(3) Fish oil mixed, according to requirements, with tallow and potash.

PREPARATION OF COMMERCIAL DÉGRAS.

The white liquor from the shamoying process, or the oil obtained therefrom, and known as pure *dégras*, *mollo*, or *moëllon*, is only partially employed in commercial dégras; even the Paris makers, recognised as the best producers of dégras, only using it as an adjunct. When the waste product of shamoying no longer sufficed to supply the demand, factories were erected to treat skins with the sole object of producing moëllon, soaking them in oil and then washing them with potash, many times over until the skins are completely destroyed. This product forms one constituent of commercial dégras.

For its production are required a copper pan, a wide wooden vat, a stirrer and a filter for sifting. The materials are moëllon, fish oil, wool fat, and commercial marble or freshly burned white lime, the latter converted into hydrate by means of 30° Bé. caustic soda, for which purpose 50 kilos of soda lye are required per 100 kilos of white lime.

In the first place 80 kilos of fish oil and 2 kilos of marble or lime are placed in the pan (which must be large enough to hold double the quantity) and heated to boiling for an hour with continual stirring in order that the two may combine thoroughly and the marble be prevented from subsiding to the bottom and giving rise to charring, which would make the oil dark or black and unfit for use. The mass froths up strongly; after the surface has become clear again the contents are passed through a fine silk gauze sieve into the vat and cooled down to 45° C. Meanwhile, 50 kilos of rain or river water are heated to 30° C. in the pan, along with the residue left in the sieve, and when the mass in the vat has cooled to the prescribed temperature, the said water is run into it in small portions through the sieve, and stirred the while. When all the water has been incorporated, the stirring is continued until the mass is perfectly cold and it is then left at rest; the product will have the same degree of consistency as a soft butter.

On the following day 200 kilos of moëllon are stirred in, without heating, followed by a mixture of 100 kilos of wool fat, 50 of fish oil, 10 of tallow and 10 of palm oil, previously warmed to 40° C. in the pan and stirred until thoroughly intermixed. The whole is then kept stirred until perfectly cold, and at the end of twelve hours, by which time it will have attained a soft buttery consistency, can be packed into the transport casks. If the water has been used too hot, or the above temperatures exceeded, the dégras will be quite fluid, water will separate out on standing and the mass soon become infested with mould.

Forty kilos of pale (*e.g.*, Greenland) fish oil are warmed and then mixed by stirring with

½	kilo	caustic lime from marble, and
15	kilos	water, followed by
100	,,	natural dégras,
10	,,	light fish oil,
15	,,	Lagos palm oil,
40	,,	purified wool fat, and
30	,,	water.

This dégras contains in percentages:—

Pale fish oil, 20 per cent.; mollo (dégras), 40 per cent.; palm oil, 6 per cent.; wool fat, 16 per cent.; water, 18 per cent.; and by reason of its content of soap and albuminoids protects the leather from drying up and preserves it for a long time.

WIENER ON DÉGRAS.

A deep pan is selected for heating by direct fire; or, if steam be at disposal, a wooden vat, arranged for steam heating. In either case stirrers are provided, these appliances consisting of a vertical shaft (passing down the centre of the pan and driven by gearing overhead), to which are attached several lateral arms, describing circles when the shaft is

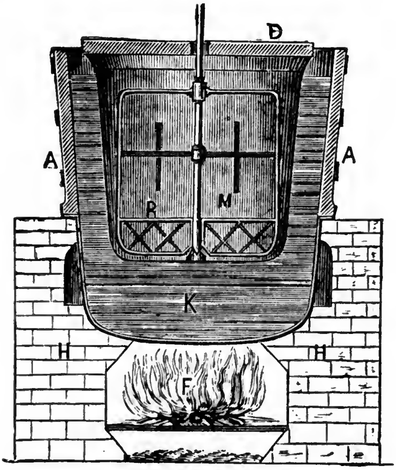


FIG. 61. Pan, with Stirrers, for Preparing Dégras.

revolved, and keeping the contents of the pan in continual motion. When fire heat has to be employed it is advisable not to let the flames come in direct contact with the pan, but to surround the latter with a water jacket as shown in Fig. 61.

The pan K, mounted in the brickwork setting H, is surmounted by a wooden extension A, with which it makes a watertight connection, so that by this means the pan M, wherein the dégras is prepared, can be placed in a higher position. R represents the stirrers, and D a wooden lid covering the pan M. By this arrangement the temperature in the latter vessel can never exceed boiling heat, and consequently the contents are prevented from charring.

A solution of 5 kilos (11 lb.) of potash in 10 litres (2·2 galls.) of cold water, prepared a day in advance by stirring up and then allowing to settle in a suitable vessel, is placed in the pan and 90 litres (20 galls.) of water are added thereto, the resulting weak lye being heated to boiling, and a few kilos of fish oil run in as a thin stream with constant stirring. The heating and stirring are continued until a sample taken out is found, on cooling, to have the consistency of dégras.

The operation may also be modified by making an emulsion of fish oil with concentrated potash lye in the pan and then adding water until the proper consistency is attained.

Olein Dégras.

The olein or oleic acid obtained as a lye product in candle-making can be advantageously utilised for the preparation of a very useful dégras, which is, however, inferior in its properties to that produced from fish oil.

The mode of preparation is the same in both cases, the operation commencing with the running of the olein into the boiling caustic soda lye. The formation of the milky liquid is generally effected more quickly than when fish oil is used, and then follows the addition of potash lye and stirring until the product is finished.

If the latter seems from the quickly cooled sample to be still too liquid, a suitable quantity of olein soap is added to the (still warm) mass in the pan. In order that the soap may quickly dissolve without leaving any residue, it is essential that it should be cut into thin strips and the stirring continued until no white flakes of undissolved soap can be detected in a carefully examined sample taken from the pan, but the mass appears perfectly homogeneous.

Many practical men are of opinion that a brown-coloured dégras acts more powerfully than a pale one, a supposition that is nevertheless without foundation, the brown coloration depending merely on the use of dark-coloured materials in preparing the dégras. The demand for dark-coloured products can easily be met by the employment of a suitable colorant added to the hot mass, a highly concentrated extract of tan or tannin being the most suitable for the purpose. The liquid in question is run in as a thin stream into the hot dégras and stirred until the colour is uniform; it is, however, of course necessary to see that the dégras preserves its salve-like consistency. When spread out rather thickly over a glass plate and held up to the light, well-prepared dégras should transmit the light uniformly without displaying any dark patches in the mass.

DÉGRAS FROM WASTE FAT.

By suitable treatment any fat which, by reason of exceeding impurity, is scarcely fit for any other purpose, may be converted into dégras. Thus, for example, a very useful and high-priced dégras can be prepared from the dark and repulsive smelling fat obtained by boiling bones that are already in an advanced stage of putrefaction.

For this purpose the fat is heated in a pan for half an hour to 120° to 130° C., with continued stirring (whereby a very disagreeable smell is given off), and is then stirred with 4 to 5 per cent. of a ½ per cent. soda lye, followed by the potash lye as in the case of the dégras made from fish oil. In this manner is obtained--generally without any soap being required for thickening—a brown dégras fulfilling all the requirements that can be exacted of the product.

BLACK DÉGRAS

can be prepared by stirring into the hot dégras, coloured with tan or tannin extract, some green vitriol (ferrous sulphate) dissolved in a small quantity of water, whereupon the entire mass will turn a deep black. Such dégras forms an excellent emollient for black leather.

WOOL FAT (WOLLFETT, WOLLSCHWEISSFETT, SUINT).

Raw Material.—The wool of the sheep, which contains a considerable quantity of this fat.

Preparation.—By extraction with carbon bisulphide, petroleum spirit, etc., in the usual or specially constructed apparatus. The crude fat contains also decomposition products of gelatinous and albuminoid bodies, to which the dark colour of the substance is due. If these products be successfully removed before they have undergone decomposition, a pale yellow wool fat is obtained, with gelatine and albuminoids as bye-products. To this end the best material to employ is the solution of wool fat obtained by extracting the crude fat or dissolving it in suitable solvents. This is treated with a small addition of syrupy phosphoric acid or the subjoined precipitants: pyro- and meta-phosphoric acids, acetic acid, lead acetate, tannic acid—well stirred up and mixed without interrupting the stirring—with 2 per cent. of benzine, alcohol or strong spirit. In a very short time the precipitated bodies will have settled down. The amount of phosphoric acid, etc., necessary for the precipitation varies with the origin of the wool and the content of fat, and must be ascertained beforehand, but as a rule will not exceed 2 per cent. of the fat. The clear and now pale yellow coloured benzine solution separated from the precipitate resulting from the above treatment can be evaporated without delay, and will leave behind a pale yellow fat. If, instead of ordinary wool fat, neutral wool fat is desired, the solution resting on the precipitate is not first evaporated, but is treated with aqueous alkali, heated and well stirred up, the aqueous layer containing the resulting soap being separated, after standing a little while, from the supernatant solution of neutral fat in benzine. If the separation is attended with difficulty it may be facilitated by the addition of a little alcohol or spirit. The benzine containing the neutral fat can then be evaporated or may be first treated with calcium chloride for the removal of any particles of water (and traces of soap dissolved therein) in suspension.

The separation of the gelatinous and albuminoid bodies from the wool fat is easily effected in the above-described manner, provided the crude fat, or fatty matter from which the fat has been dissolved by benzine or the like, has not been previously subjected to prolonged heating. If, however, the fat in the benzine solution employed has already been once heated to completely expel the solvent, or brown, commercial wool fat obtained from crude wool fat by hot pressing or similar methods is used, then the separation of the gelatinous and albuminoid matters by the aforesaid precipitants is, by reason of the partial decomposition undergone by the former, incomplete. The product is, it is true, paler than the original material, but will not be a light-coloured yellow fat. It is, therefore, necessary to lay particular stress on the selection of a material in which the gelatinous and albuminoid bodies have not suffered decomposition. The precipitation of the extraneous matters is best effected by using highly concentrated acids, such as the syrupy ortho-, pyro- and meta-phosphoric acids, glacial acetic acid, etc. Alcohol by itself will not produce any precipitate. The simultaneous or successive action of the aforesaid precipitants and alcohol on the dissolved wool fat, with the object of precipitating the gelatinous and albuminoid matters, is difficult, and it is necessary, after ascertaining the presence of such bodies in the wool fat, to find the reagents suitable for their precipitation, since they cannot be deduced simply from scientific chemical data, the aforesaid precipitants being unable of themselves to throw down matters from the solution of wool fat, this result only ensuing on the addition of alcohol, which latter substance again is, by itself, incapable of effecting precipitation.

Properties.

Specific Gravity.—At 15° C., 0·973 (Schaedler).

Melting-Point.—39° to 42·5° C. (Stöckhardt).

Crude wool fat is a greasy, unpleasant-smelling, yellow or brown mass which, by reason of its high content of cholesterin, isocholesterin, stearic- and palmitic-cholesteryl-ether, and creatic-oxylether, is only imperfectly saponifiable. Moreover, it contains, in addition, glycerides among which occur those of the lower fatty acids (*e.g.*, valeric acid) and potash soaps of the said acids. When subjected to distillation it yields *distilled wool fat* which has the following characteristics :—

Melting-point, 42° C. ; setting-point, 40° C. ; melting-point of the fatty acids, 41·8° C. ; setting-point of the fatty acids, 40° C. ; saponification value of the fat, 169·8 ; of the fatty acids, 170·8 ; iodine number, 36·0 (Hübl).

Distilled wool fat consists almost exclusively of free fatty acids and cholesterin. When treated in the usual manner for the separation of the insoluble fatty acids a white mass is obtained, which, in a few days, turns yellow and then orange, and, by reason of the presence of volatile fatty acids, resumes the characteristic smell of wool fat.

Purified Wool Fat

is met with in commerce under the names of *lanolin* and *Adeps lanæ.* The crude fat, which under the designation of *Œsypus* was employed for medicinal purposes by the ancients, is a brown evil-smelling mass. According to Jaffé and Darmstädter the following means are employed for its purification. The soaps present in wool fat are converted into insoluble fatty salts by means of aqueous solutions of salts of the alkaline earths, or by metallic sulphides, and the mass treated in the centrifugal separator. It is then extracted by boiling acetone, wherein the wool fat alone is soluble, and this substance is recovered by cooling the solution or distilling of the acetone. The crude wool fat treated with alkaline earths can also be dissolved in benzine, benzol, xylol, toluol, isobutyl alcohol, amyl alcohol, or carbon bisulphide, and the soaps thrown down by an addition of acetone. Instead of centrifugal force, lime water and an aqueous solution of a salt of an alkaline earth can be used for separating the wool fat from the wool washings. The soap in precipitating breaks up the emulsion and causes the separation of the fat, which can then be skimmed off, and, when treated with alkalis, be made to yield up its fatty acids. When the products of the reaction are treated with methyl- or ethyl alcohol lanolin is left behind insoluble. Also in treating wool fat with alcoholic potash the pure wool fat remains undissolved. The wool fat is made into an emulsion with ammonia, and strong alcohol is added, whereupon the pure wool fat is precipitated ; and it is this fat that, when kneaded with water, is put on the market as "lanolin". It melts at 40° C. and can absorb as much as 105 per cent. of water without losing its salve-like consistency. Being saponifiable with difficulty, and therefore not becoming rancid, it is used as a basis for salves, an adjunct to cosmetic soaps, etc. A. von Rad removes the colouring and odorous matters of crude wool fat by treating them with oxidising agents, such as bleaching powder, or permanganate, in an alkaline solution, the wool fat being extracted with strong alcohol, benize, sulphuric ether, benzol, ether and chloroform.

In order to obtain perfectly neutral products wool fat is esterified in admixture with oleic acid, of which no further addition is, however, necessary, this acid being present in the raw material. This is treated with alcohol and sulphuric acid (66° Bé.). Rad designated the mixture of cholesterin ethers (wool fat) with the neutral ethers of oleic and ricinoleic acids by the name of "lanesin". The "Norddeutsche Woll-kämmerei u. Kammgarn-spinnerei" prepares neutral wool fat by adding to the crude wool fat, thrown down from the wool washings by sulphuric acid, some fat solvent such as benzine or carbon bisulphide either before or after neutralisation and following this up at once by a solution of common salt, magnesium chloride, sodium sulphate, etc. The soap is hereby separated from the dissolved wool fat, which can be recovered by evaporating the solvent. The use of sulphuric acid in this process may be superseded by sulphurous acid, which prevents putrefaction of the washings. The product so obtained is introduced into commerce under the name of *Adeps lanæ* for pharmaceutical purposes. J. Roos emulsifies wool fat with boiling water and soda solution, the layer of unsaponified cholesterin collecting on the surface being skimmed off and the residual emulsion treated with dilute acid for the recovery of the fatty acids, which latter are employed in soap-making under the name of "patent fat".

SPERMACETI (WALRATH, SPERMACET).

Raw Material.—The fat found in the skull cavity of the cachelot or sperm whale, and in other species of dolphin. In the living animal the spermaceti occurs dissolved in sperm oil, and separates out after death.

Preparation.—When the skull is opened the fatty mass is collected and stored in large vessels, the liquid sperm oil being filtered off and the residue, consisting of a mixture of spermaceti and sperm oil, is pressed, and leaves behind a crystalline fatty mass. This is next treated with a weak lye of caustic potash or soda, to saponify and remove any adherent oil, after which it is repeatedly washed with water and re-melted over boiling water.

Crude spermaceti, which is seldom met with in commerce, forms plates with a foliaceous structure and of about the thickness of the finger; is transparent and has a fishy smell. The purified article comes to market in the shape of semi-transparent white, broad, foliaceous, crystalline lumps handling like talc. According to Benedikt spermaceti is obtained from sperm blubber by pressing.

Properties.—Spermaceti is solid, tasteless, inodorous, and may be crumbled between the fingers.

Specific Gravity.—At 15° C., 0·960 (Dieterich); 0·943 (Schaedler).

Melting-Point.—43·5° to 44·1° C. (Rüdorff); 45° C. (Barfoed); or, according to Schaedler, between 50° and 54° C.

Setting-Point.—43·4° to 44·2° C. (Rüdorff); immediately below the melting-point according to Schaedler.

Saponification Value.—108·1 (Becker).

If the product be treated several times with hot alcohol, the residual substance has a melting-point about 5° C. higher than before. It may be distilled at 360° C. without any noticeable decomposition. When applied in a melted condition to paper, it leaves no grease spot behind. It is very slightly soluble in cold 98 per cent. alcohol, and quite insoluble in 90 per cent. spirit, but, on the other hand, dissolves easily in hot alcohol, and crystallises out again for the most part on cooling. Its solutions do not redden litmus paper. According to Schaedler, 1 part of spermaceti is soluble in 40 parts of boiling alcohol of specific gravity 0·831, the greater part separating out on cooling. It is, moreover, but slightly soluble in benzine and petroleum spirit, though readily soluble in ether, chloroform, or carbon bisulphide. Spermaceti is a mixture of various fats, but contains no glycerides; on recrystallisation from alcohol the crystalline sperm fat—cetin—palmitic-cetyl ether, formerly called cetyl-oxide cetate or æthal æthalate, separates out. On evaporating the alcoholic solution, a residual oil, the cetinelain of Berzelius, is left, which saponifies with difficulty and yields thereon cetinelaic acid, an acid not identical with oleic acid. It forms a lead salt insoluble in ether, and the product does not give off any smell of acrolein when subjected to dry distillation. According to Benedikt, spermaceti can be easily saponified with alcoholic caustic potash, cetyl alcohol being thrown down on diluting the solution with water.

According to Schaedler, spermaceti can only be saponified with difficulty; it contains other compounds which yield on decomposition stearic, myristic and palmitic acids, as well as the alcohols corresponding thereto, and named by Heinz *stehal*, *methal* and *lethal*. The elementary composition of spermaceti is as under:—

Carbon - - - - - - - -	80·03 per cent.
Hydrogen - - - - - - - -	13·25 ,,
Oxygen - - - - - - - -	6·72 ,,

Adulterations.—Spermaceti cannot be easily falsified, since its properties are very remarkably modified by every admixture that may be made, and adulterations are readily recognisable by the increased hardness of the substance, its lack of nacreous lustre, and the small foliaceous crystalline structure. According to Schaedler, wax is frequently added to spermaceti, but the quantity must not be so large as to raise the specific gravity and melting-point or cause the ethereal solution to appear milky. Tallow betrays itself by its odour when melted or by the smell of acrolein produced when a lighted wick steeped in the substance is blown out again; moreover, spermaceti containing tallow leaves a greasy mark on paper. If stearic acid be added, the spermaceti is hardened, the crystals are reduced in size and the mass froths up when heated with soda solution. The saponification value is utilised for the detection of paraffin.

In order to test spermaceti for stearic acid, a sample is melted in a basin, ammonia added, and the whole stirred and left to cool, the spermaceti being removed when set, and the stearic acid thrown down from the aqueous solution by hydrochloric acid. On prolonged exposure to the air spermaceti becomes yellow and rancid, but can be made fit for use again by re-melting and treating with dilute caustic potash or soda lye. Spermaceti is scarcely affected by boiling with dilute sodium carbonate solution, differing in this respect from stearine.

The testing of spermaceti is performed (according to Kebler) as follows: The melting-point varies between 42° and 47° C., whilst that of cetin is between 48·9° and 55·5° C. The specific gravity at 15° C. is from 0·905 to 0·943, and is, throughout, not so near to the latter figure as formerly assumed. The saponification value ranges from 125·8 to 134·6, whilst the acid number exhibits wide fluctuations (0·0 to 5·17) as the age of the sample increases.

Uses of Spermaceti.—Medicinal: for salves, and formerly also as a palliative for alleviating pain and irritation. Cosmetic: in pomades, etc. Technical: for candle-making (it burns with a brilliant, smokeless flame), either alone or in conjunction with wax; as an addition to dressings (for cloth), etc.

EXAMINATION OF FATS AND OILS IN GENERAL.

The physical constants regarded as characteristic of the various fats are: the specific gravity and (for the solid fats especially) the melting-point. On the other hand the boiling-points are unreliable, since the fats are partly decomposed on heating. The specific gravity of liquid fats can be determined by means of the pyknometer, the Sprengel tube or the Westphal hydrostatic balance. The Sprengel tube consists of a U tube, both ends of which are drawn out as capillaries bent outwards at right angles from the limbs. The tube is completely filled with oil by dipping the one end in the liquid and exhausting the air through the other. The excess of oil overflowing is wiped away carefully with filter paper and, when the expansion of the oil has ceased, the tube is taken out of the flask and weighed after cooling. The specific gravity is calculated after the weights of the tube, when empty and filled with water, are known.

The Westphal balance is shown in Fig. 62. The thermometer displaces a definite volume of oil so that the loss in weight gives the weight of this quantity of oil.

The melting-point of solid fat can be determined by the methods generally practised. A capillary tube is filled with the melted fat and, when the latter has cooled and solidified, is attached to a delicate thermometer which is then immersed in a beaker of water. The latter is gradually heated until the melting-point of the fat is reached and the fat liquefies in the capillary tube, the temperature at which this occurs being read off on the thermometer. To increase the accuracy of the estimation the beaker of water is placed in a second vessel and heat applied to the latter.

A number of chemical reactions have been proposed for differentiating between the various fats and oils. Many of these reactions are unreliable and the results contradictory one of another, on account of their dependence on special conditions, so that no great value can be attached to them. This applies particularly to the majority of the colour reactions produced by the influence of sulphuric and nitric acids on the various oils. The different increases of temperature, occasioned by the addition of concentrated sulphuric acid to oils, are also insufficiently reliable.

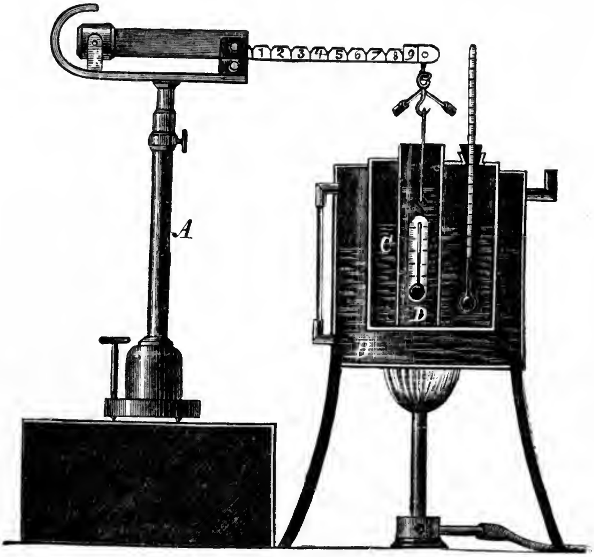


Fig. 62. Westphal Balance.

On the other hand sundry quantitative methods may be successfully employed in the differentiation of the various fats, and serve to determine the quantitative ratio of the different classes of bodies in a fat, as well as for identifying the individual fats, their content of the individual substances often differing characteristically.

To these quantitative methods belong: the acid number; saponification value; ether number; Reichert-Meissl number; Hehmer number; acetyl, bromine and iodine numbers; the importance of which, after having already been repeatedly cited in the present work, is now acknowledged.

1. The *acid number* indicates the number of milligrams of potassium hydroxide required for the neutralisation of the free fatty acids present in a fat. It is ascertained by titrating the alcoholic (or other) solution of fat by alcoholic or aqueous caustic potash.

2. The *saponification value*, the determination of which was prescribed by Köttstorfer, and which is also styled the *Köttstorfer number*, is ascertained in the following manner: 1·5 to 2 grams of the fat are treated for fifteen minutes on the water bath with 25 c.c. of ½-normal alcoholic caustic potash; when saponification occurs 1 c.c. of alcoholic phenolphthalein solution is added, and the liquid is titrated with ½-normal hydrochloric acid. A blank experiment is then performed in the same manner by titrating another 25 c.c. of the alcoholic potash. The difference between the number of milligrams of potassium hydroxide employed and that found by back-titration is calculated to 1 gram of fat, and the result gives the saponification value. The amount of fat saponifiable by 1 equivalent (56·1 parts) of KHO is called in England and America the *saponification equivalent* of the fat.

3. The *ether number* relates to the number of milligrams of potassium hydroxide required to saponify the neutral fat in 1 gram of sample.

4. The *Reichert-Meissl number* gives the quantity of vola-

tile fatty acids contained in a fat. It indicates the number of c.c. of $\frac{1}{10}$-normal caustic potash requisite for neutralising the volatile fatty acids (soluble in water) obtained from 5 (formerly 2·5) grams of fat.

Five grams of fat are saponified by 2 grams of solid alkali and 60 c.c. of 70 per cent. alcohol in a 200 c.c. flask on the water bath, the alcohol being then evaporated, the mass dissolved in 100 c.c. of water and distilled after the addition of 40 c.c. of (1 : 10) sulphuric acid. One hundred and ten c.c. of the distillate are collected in a graduated flask, and 100 c.c. of this, being filtered into a second graduated flask, are titrated with $\frac{1}{10}$-normal alkali, with litmus or phenolphthalein as indicator.

5. The *Hehner number* gives the amount of insoluble fatty acids in 100 parts of fat. Three to 5 grams of fat are saponified with 50 c.c. of alcohol and 1 to 2 grams of caustic potash. The soap, after the expulsion of the alcohol, is dissolved in 100 to 150 c.c. of water, qualified with hydrochloric or sulphuric acid, and the fatty acids passed, after melting, through a filter dried at 100° C., the mass being washed with water until the filtrate ceases to give an acid reaction.

6. The *acetyl number* denotes the quantity of oxy-fatty acids or fatty alcohols in the fat. Twenty to 50 grams of the non-volatile fatty acids are acetylised by two hours' boiling with acetic anhydride, the product of the reaction being boiled repeatedly with 500 to 600 c.c. of water, the (now neutralised) acids filtered in the air oven, and the acetyl acid number and the acetyl number ascertained by titration with aqueous $\frac{1}{2}$-normal alkali.

Bromine and Iodine Absorption.—The methods for determining these values give the percentage quantities of bromine and iodine absorbed by oils under conditions favouring the exclusive formation of addition products. The fatty acids of the acetic or stearic series are saturated bodies giving no addition products with bromine or iodine, whereas the acids of the acetyl or oleic series combine with 2 atoms of a halogen, and those of the propiolic or linolic series with 4 atoms.

The glycerides of the acids of these series behave like the free acids, so that the estimation of the percentage of iodine absorption forms a measure of the ratio of olein to palmitin and stearine in a fat, and also for the content of linolein in a drying oil in comparison with the oil-content of a non-drying oil.

The determination of the bromine absorption gives no reliable values, whereas the iodine number by the Hübl method yields more constant results. Hübl employs an alcoholic mixture of iodine and mercuric chloride; 25 grams of iodine being dissolved in ½ litre of 95 per cent. alcohol (free from fusel oil) and 30 grams of mercuric chloride (also in ½ litre), the solution being ready for use after twelve hours' standing. Its content must be ascertained immediately prior to use, every time. For estimating the iodine number, 0·2 to 0·4 gram of a liquid (or 0·8 to 1 gram of a solid) fat is weighed out and dissolved in 10 c.c. of chloroform. Then 20 c.c. of the iodine are added, 5 to 10 c.c. at a time, until the solution, at the end of two hours, has assumed a dark-brown colour, whereupon 10 to 15 c.c. of a 10 per cent. aqueous solution of potassium iodide and 150 c.c. of water are run in. The free iodine is then titrated with a (24 grams per litre) solution of sodium thiosulphate (hyposulphite), and the absorbed iodine calculated to percentage units of the fat, the resulting value being termed the iodine or Hübl number.

This number seems to be approximately constant for each oil, or class of oils, and is highest in the case of the vegetable drying oils. The Hübl method has proved extremely useful for the detection of cotton-seed oil in tallow and lard. Pure cotton-seed oil has the iodine number 109·1;

pure tallow, 40·8; tallow with 5 per cent. of cotton-seed oil, 44; with 10 per cent., 47·1; with 15 per cent., 49·7; with 20 per cent., 52·9; with 25 per cent., 56·1; with 30 per cent., 59·2; and with 40 per cent., 66·2. In the case of lard detection is rendered more difficult by the presence of beef stearine. Pure lard has an iodine number of 57 to 63; beef stearine, 23 to 28.

In the examination of fats it is not merely a question of identifying a certain fat and establishing its purity, but regard must also be had to the presence of soaps, free fatty acids and extraneous non-fatty matters, such as resins and hydrocarbons. Soaps may be removed by shaking up the carbon bisulphide solution of the fat with water. The presence of free fatty acids in fat cannot always be considered an adulteration, since they are generally present in many vegetable oils. Occasionally, however, the occurrence of free fatty acids indicates decomposition (rancidity) of the fat. In the absence of free fatty acids, resin can be detected by shaking up the oil with moderately strong alcohol and evaporating the latter. The separation of resin acids from free fatty acids is most suitably effected by the method prescribed by T. S. Gladding, which is based on the ready solubility of silver resinate in ether, whereas silver nitrate, etc., are almost completely insoluble therein. Hydrocarbons can, in general, be detected by saponifying the sample with alcohol potash (5 grams of oil, 2 grams of potassium hydroxide, 25 c.c. of 90 per cent. alcohol), the resulting soap being mixed with pure sand, the alcohol driven off by evaporation on the water bath at a temperature not exceeding 50° C., and the residue extracted with ether or petroleum spirit, the hydrocarbons present being left behind on the evaporation of the solution.

FINIS.

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