General Discussion of Processing Edible Oil Seeds and Edible Oils

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IN attempting to cover this broad field which includes a number of processes and processing steps our discussion of each process must necessarily be brief. We cannot touch on all the changes that have occurred as our processing methods developed to their present status. However a little of the history of the industry may be interesting and will serve to explain some of the trends in development.

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Man's first successful efforts at obtaining oil from oil seeds and the uses of the oils are lost in antiquity. The first record of cottonseed being crushed for oil seems to be contained in old Hindu medical books. The method consisted of reducing the seed by pounding and then boiling the material in water for obtaining the oil (1). Soybean oil has been a component of the Chinese diet for close to 5,000 years (2), and the Chinese are said to have obtained oil by crushing seed to a meal under an edgestone, heating the meal in open pans, and pressing in wedge presses (1).

A very simple form of the wedge press consisted of a box or container into which were placed bags of the oil-bearing material. Wedges were then driven in beside the bags to apply pressure for expression of the oil. At a later date several types of lever presses and hand-powered screw presses were invented by the Greeks and Romans (3).

In our own country several factors combined at the end of the 18th century and during the first half of the 19th century to get the cottonseed crushing industry on its way:

a) The invention of the cotton gin stimulated the production of cotton since it eliminated the large amount of hand labor required for separating the fiber from the seed.

b) The development of improved spinning and weaving machinery added further impetus to cotton production (1).

c) Disposal of cottonseed at the gins became a problem. Some gins merely moved away from the piles of seed as sawmills now move away from piles of sawdust. Others dumped the seed into streams. These seed became a nuisance, and finally several states passed laws requiring gins to remove or destroy all seed resulting from their operations (1).

d) A satisfactory huller for cottonseed was developed (1).

e) The first successful hydraulic press was built (3).

Extraction

1. *Hydraulic.* The hydraulic box press as we know it today has served the cottonseed and other oil seed crushing industries for many years. Until recent years most of the processing of oil seeds in this country was carried out by the hydraulic method.

In the usual hydraulic procedure the first step is to pass the seeds, or the oil-bearing portions of the seeds, between heavy crushing rolls where they are reduced to flakes of about 0.010 in. thickness. This crushing or rolling puts the material in a form which facilitates uniform cooking and rupture of the oil cells.

Several types of cookers are employed, but the one most commonly used is the stack cooker which consists of several (usually 4 to 6) steam-jacketed vessels mounted one above the other. These jacketed vessels or kettles have openings in their bottoms and gates for controlling the flow of material.

The flaked meats enter the top kettle and flow successively through the lower ones. The levels of meal

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in the kettles may be automatically controlled so that a withdrawal of cooked meal from the bottom kettle will be replaced automatically by a flow of meal from the upper kettles. This is known as continuous cooking. In batch cooking no material from an upper kettle is allowed to flow down until the kettle immediately beneath it is empty. Then the entire batch from a kettle is dropped to the one below. There has been much discussion concerning the merits and demerits of these two methods of cooking. In the opinion of the writer the batch method gives more uniform cooking and slightly better extraction. On the other hand, continuous cooking is more easily controlled and lends itself to more flexible operation.

Regardless of the method employed, the meats are cooked under controlled conditions of temperature, moisture, and time. Some of the reasons given for cooking are (1):

a) to rupture or finish rupturing the oil cells,
b) to reduce the viscosity of the oil by higher temperature,
c) to facilitate separation of the oil from proteinaceous materials by coagulation of the proteins,
d) to dry the cooked meal to the proper moisture content for pressing, and
e) in the case of cottonseed to detoxify the free gossypol by converting it to the bound form.

In the early years of oil milling the prime objective was to get tonnage through the mill. Later the operators became more conscious of the fact that variations in cooking had a decided effect on the yield of oil. During the past few years much study has been devoted to methods of cooking which would produce not only high efficiency in oil recovery but also oils of good quality and meals of high nutritive value.

The next step after cooking is the forming of the cake. A press cloth of the width of the cake and several inches more than twice as long as the cake is spread in what is known as the former bed. A container, called the former buggy and hydraulically operated, moves from beneath the cooker and spreads a layer of cooked meal over the press cloth in the former bed. The buggy returns to its position under the cooker, and the ends of the press cloth are folded over the meal and lapped about 2 inches on top. A cover is brought down, and a slight hydraulic pressure is applied to compact the material so that it can be handled and placed in the press box. A flat metal "pan" is slipped under the cake, and it is transferred to the press by hand.

After the press is filled with cakes, hydraulic pressure is applied to the ram which transmits pressure to the cakes. The valves through which the hydraulic fluid is admitted are so constructed that they automatically control the rate at which the pressure is applied. Control of the rate of pressure application has an important bearing on extraction results. The optimum rate will vary with the oil content and other characteristics of the material being pressed. The maximum pressure applied is about 2,000 lb. per square inch of cake area. Within reasonable limits an increase in the time during which the press remains under pressure will increase the oil recovery. The time under pressure will usually be within the range of 30 to 60 minutes and will be determined by the price of oil and other economic considerations. After the pressure is released, the cakes are removed from the press by hand and the cloth is stripped off for reuse.

We might mention here that prior to World War II most of the press cloth used in this country was woven from human hair. This cloth was strong, maintained its porosity for oil drainage, and was able to withstand the pressing temperatures. Wool was used after the war had cut off China as a source of human hair. Later nylon was used, and today most of the cloth is wool or nylon. The nylon is more expensive on a per pound basis, but this is offset by its longer wearing qualities.

2. *Screw Press or Expeller.* Screw presses or Expellers have an advantage over hydraulic presses of about 1.5% oil in cake. They also have the advantages of requiring no press cloth and less labor. The product oil requires filtration, and the saving on press cloth is partly offset by the cost of filter cloth. Power requirements are higher than for hydraulic.

In some areas recent years have seen a growing scarcity of labor for hydraulic press rooms. There are instances where this has been a contributing factor in the decision to convert from hydraulic to Expellers or screw presses. Most of this conversion has been in mills crushing cottonseed and peanuts. To a large extent the soybean industry started with this type of processing just as the cottonseed industry attained its growth with the hydraulic press.

The preparation for this type of pressing is similar to that for hydraulic operation. The rolling or crushing operation is somewhat less critical, cooking temperatures are usually higher, the moisture at the time of pressing is lower, and the cooking time is frequently shorter.

Pressing is accomplished by means of a heavy screw which forces the material under high pressure into the barrel of the machine. The barrel consists of a tube which is built up from a series of bars. Slots between the bars allow the oil to flow out as pressure is applied. The width of the drainage slots, referred to as barrel spacing, will usually be in the range 0.005 in.-0.025 in. The optimum depends on the type of material being processed. The slot width is controlled by spacers placed between the bars and frequently will vary from one section of the barrel to the other.

During the past two years a number of operators have increased the speeds of their screw presses and Expellers in order to obtain higher capacities. Cecil Chandler of the Lubbock Cottonoil Company is credited with being the first to try this type of operation. He doubled the capacity of his machines with little or no loss in extraction efficiency. Contrary to the original slower speed operation, it appears that a thorough job of rolling and cooking must be done if good extraction is to be obtained in this high speed operation.

3. *Solvent Extraction.* The conversion to solvent extraction by the soybean industry has taken place in the past two decades. Conversion by the cottonseed industry started in 1946 with the plant at Wilson, Arkansas, and has gained momentum in the past three years. There are at least two good reasons for the earlier and more rapid conversion by the soybean industry: a) the gain in oil per ton of seed is greater for soybeans; and b) cottonseed are more difficult to handle by the solvent process. The first point is illustrated in Table I. To avoid any confusion on these figures it should be pointed out that the cottonseed processor does not suffer any loss in meal yield when the oil content of the meal is reduced. Hull is used to

TABLE I

Typical Extraction Results

	Cotton-seed	Soy-beans
Meal yield—lbs./ton	850.0	1600.0
% Oil in hydraulic meal	5.5	5.5
% Oil in Expeller or screw press meal	4.0	4.0
% Oil in solvent extracted meal	0.8	0.8
Oil gain Expeller or screw press *vs.* hydraulic—lbs./ton	12.8	25.0
Oil gain solvent *vs.* Expeller or screw press—lbs./ton	27.2	50.8

replace the additional oil removed so the meal yield and the protein content of the meal remain constant. Thus a reduction of 1.5% oil on 850 lb. of meal means a saving of 12.8 lb. of oil. This is not true in the case of the soybean processor. If the original yield is 1,600 lb. of meal at 5.5% oil, a reduction in oil content to 4.0% means reducing the meal yield to 1,575 lb.

At present there are at least seven types of continuous extractors operating on oilseeds in this country. These may be roughly divided into two groups, a) total submergence types and b) percolation types. The Hildebrandt, Allis-Chalmers, and Anderson fall within the first group while the Bollman, Rotocell, and De Smet are included in latter group. The flow of solvent is counter to the flow of material being extracted except for the Bollman, where a portion of the flow is concurrent. In the submergence types, as the name implies, the material to be extracted is submerged in the solvent. In the percolation types the solvent and miscella are circulated by pumps and percolate through beds of the material to be extracted. One of the advantages claimed for the percolation type is the filtering action, which removes fines from the miscella as it passes through the beds.

Several other solvent extraction processes have been developed or are being developed in this country. These include the filtration extraction process by the Southern Regional Research Laboratory and the vibrating extraction process by Allis-Chalmers.

Edible oils being obtained by solvent extraction include cottonseed, soybean, peanut, corn, and coconut.

Two methods of operation are currently used and are referred to as the direct and prepressing methods. In the direct method the material is usually conditioned by heat and moisture and then flaked for extraction. In the prepressing method the material is cooked, about two thirds of the oil is expressed in screw presses or Expellers, and the cake from these machines is conditioned and flaked or granulated for solvent extraction.

Practically all soybean processors use the direct method. The cottonseed industry is divided between the two methods, with the major portion using the prepressing method. In the case of cottonseed the prepressing operation tends to minimize some of the problems in the extraction step, such as fines in miscella and dustiness of the meal produced. The cooking and prepressing operations also tend to reduce the free gossypol in the meal. One processor using direct extraction has worked out a chemical treatment for inactivating the gossypol. The economics and advantages of the two methods are still open to discussion, and it is too early to predict which will predominate in the cottonseed industry.

Some peanuts are being processed by the prepressing method. In fact, some mills equipped for prepressing will handle a crush of cottonseed and a crush of peanuts during a single year of operation.

Regardless of the method used, the material to be extracted is contacted by the solvent which dissolves the oil. The extracted material or marc is freed of solvent as far as possible by draining or squeezing and then passed to dryers where the remaining solvent is driven off by heat. Marc entering the dryers will usually contain 35-50% solvent. Solvent vapors from the dryers are scrubbed with hot water or liquid solvent to remove meal dust and subsequently recovered in condensers for reuse.

The miscella, which is the solution of oil and solvent, is clarified and passes to an evaporator where a major portion of the solvent is removed. Several types of evaporators are used, but they are similar in that they use steam coils or tube bundles for supplying heat; and they have chambers for separating entrained liquids from the solvent vapors going to the condensers. The evaporator may operate at atmospheric pressure or under vacuum. The former is more generally the case.

From the evaporator the flow is to the stripping column where the remainder of the solvent is removed. This vessel is nearly always operated under vacuum, and sparge steam is used to help strip the last traces of solvent from the oil. The stripping column may be a bubble tray type, a packed column, or any of several other types. Oil from the stripping column usually passes through a cooler and then to storage.

In the interest of oil quality it is desirable to carry out the evaporation and stripping at as low a temperature and in as short a time as possible.

As pointed out above, the residual oil in solvent extracted meal is less than 1%. This is a close approach to the ultimate as far as oil recovery is concerned. It appears then that future development and research by oilseed processors must be directed toward reduced operating costs, improvement in quality of products, and the development of new uses for these products.

We should not leave the general subject of extraction without mentioning the phenomenal growth of the soybean industry in this country. It is said (3) that the first domestic beans were crushed in 1917. The figures in Table II show U. S. production of crude cottonseed, soybean, and peanut oils for several calendar years. Soybean oil production surpassed that of cottonseed in 1944 and has continued to increase its lead.

TABLE II

U. S. Crude Oil Production—1,000 Lb.
(From U. S. Dept. of Commerce Reports)

Calendar Year	Cottonseed	Soybean	Peanut
1922	934,627	751	22,644
1925	1,510,802	2,520	15,156
1930	1,616,102	14,387	25,495
1935	1,184,039	105,056	44,673
1940	1,274,192	533,224	83,875
1944	1,132,462	1,245,873	112,418
1951	1,417,013	2,472,833	183,739

Refining

Most vegetable oils are not suitable for human consumption in the crude state and require refining. This step removes most of the non-glyceride components, such as free fatty acids, gums, pigments, etc.

According to Bailey (1) two methods of treatment were worked out toward the end of the 18th century. One of these used strong sulfuric acid, and the other

employed strong caustic alkali. The alkali method was the one which finally came into general use.

1. *Open Kettle Method.* In kettle refining the processing vessel is an open tank or kettle and is equipped with a mechanical agitator and steam coils for heating. The size of the kettles varies, but frequently they are sized to hold one tank car of oil.

The oil, which is preferably at a temperature just high enough to insure its being melted and not unduly viscous, is pumped into the kettle and allowed to stand for a short time to settle out entrained air. Agitation is then started, and a predetermined amount of sodium hydroxide solution is introduced. The caustic combines with the FFA in the oil to form soaps and also effects the removal of meal, dirt, phosphatides, and some of the color bodies. Relatively vigorous agitation is used while caustic is added in order to obtain good distribution of the caustic. This agitation is continued for a period which may vary from 10 minutes to more than an hour, depending on the type of oil being processed. Agitation is then slowed, and the temperature is increased to obtain a "break." The break consists of the melting and agglomeration of soap particles and the other materials which go to make up the "foots." This agglomeration to particles of relatively large size facilitates the settling and separation by gravity of the foots from the refined oil. After a good break is obtained, the agitation is stopped and the foots are allowed to settle for a period of several hours. The refined oil is then decanted from the foots. The refined oil is usually further settled and/or filtered.

2. *Continuous Centrifugal Method.* In this method the caustic is continuously proportioned into the stream of crude oil. The two flow together to a high speed mixer where caustic is intimately dispersed into the oil in a matter of seconds or a few minutes at most. The mixture then flows to a heat exchanger where the temperature is increased sufficiently to melt the soap stock. From the heat exchanger the material flows to centrifugals where centrifugal force rather than gravity is used to separate the foots from the refined oil. Some refiners wash the refined oil one or more times with hot water to remove traces of soap and then separate the oil from the wash water in centrifugals. The washed oil is then passed through a continuous vacuum dryer to remove entrained and dissolved moisture.

This method has the advantage of a short contact time between oil and caustic, which reduces the saponification of neutral oil. The centrifugal force employed is many times the force of gravity and allows less neutral oil to be entrained with the foots. The overall percentage reduction in refining loss for centrifugals compared with kettle refining is in the range of 15 to 35%.

3. *Soda Ash—Caustic Soda Method.* This method is similar to the original continuous method, but the neutralization and decolorization are carried out in separate steps (1). This two-stage operation naturally requires more equipment than the original single step operation.

In the first step the oil is pumped through a preheater, and a 15-20° Be. soda ash solution is continuously proportioned into the stream of preheated oil. The amount of soda ash is about 1.5 times that required for neutralization of the free fatty acid in the oil. A mixer in the line disperses the soda ash solution into the oil, and the soda ash reacts with free fatty acids to form soap. The soda ash solution also causes precipitation of the gums in the oil. There is no loss from saponification of neutral oil since sodium carbonate will not saponify neutral oil.

The mixture passes through a heat exchanger where the temperature may be increased and is then sprayed into the "dehydrator," which is maintained under a vacuum within a few inches of the barometer. Here the moisture contained in the gums and soap is flashed off. There is less tendency for the dehydrated materials to entrain neutral oil and the solubility of the the gums in oil is reduced.

Rehydration is necessary to soften the soaps and gums so that they may be continuously discharged from centrifugals. Fortunately this rehydration does not cause a return of the original characteristics of the soaps and gums as far as solubility in the oil and the tendency to entrain neutral oil are concerned. Rehydration is accomplished by proportioning a few per cent of 20° Be. soda ash solution into the mixture. The material then flows to centrifugals where the soaps and gums are separated from the partially refined oil.

The purpose of the second step in the operation is mainly the removal of color bodies. The oil passes through a cooler where its temperature is reduced to about 100°F. A solution of 20° Be. caustic soda (1-2%) is proportioned into the stream of oil, the two are thoroughly mixed and pass to a heat exchanger, where the temperature is raised to about 150°F. The mixture then flows to centrifugals, where the soaps and color bodies are separated from the refined oil.

As in the case with the original continuous method, the refined oil may be washed with hot water, the wash water is separated in centrifugals, and the washed oil is vacuum-dried.

The soda ash method will frequently give an improvement over the original continuous method in both refining loss and bleachability of the refined oil.

A variation of the above method, referred to as "the double lye addition method," has been used. This consists of adding caustic soda in two steps. The theory is that the first caustic added would neutralize the free fatty acids and precipitate the gums, thus leaving the second portion of caustic available for color removal. Each addition of caustic is followed by mixing, but there is no heating or separation of foots until after the second lye addition.

4. *Miscella Refining.* Refining in the miscella state is practiced in some plants where solvent extraction is used. This process is similar to the original continuous method except that the oil is refined in the presence of solvent. It is necessary, of course, that the centrifugals be vapor-tight to prevent the loss of solvent.

After the refining operation the solvent is stripped from the refined oil. This operation is similar to the stripping operation in solvent extraction plants where the solvent is stripped from crude oil.

The miscella refining operation is said to give improvement in color and bleachability of the refined oil. Refining losses are low and even approach the theoretical.

Bleaching

The color of refined oils is darker than desired for use in some end products, and a bleaching operation is necessary for obtaining the required color.

Early bleaching methods included exposure of the oil to sunlight, heating with steam coils, and blowing the oil with air or steam. It is known now that most of these treatments are detrimental to the flavor and keeping quality of the oil. The effect of sunlight, for instance, is so severe that a person experienced in flavoring fats can differentiate between two samples of shortening, one of which has been exposed to direct sunlight for only a few minutes.

The use of Fuller's earth and/or activated carbon finally evolved as the most widely accepted method of bleaching. In the usual operation the bleaching agent is added to the oil in a tank which is equipped with a mechanical agitator and coils for heating and cooling. The mixture is heated to 180-220°F. and agitated for a period of time to allow the action to take place. The bleaching agents present an enormous amount of surface area and remove color from the oil by adsorbing color bodies onto these surfaces.

After the bleaching operation the mixture may be cooled by circulating water through coils in the tank. The mixture is then pumped through any conventional type of filter, where the spent bleaching agent is separated from the bleached oil.

In recent years some bleaching has been done under vacuum. It is claimed that this increases the efficiency of the bleaching operation and improves the quality of the oil. Certainly the removal of most of the oxygen of the atmosphere during this processing should have a beneficial effect on the quality of the fat.

Winterizing

Many of our edible oils contain glycerides of saturated fatty acids which will solidify and separate from the liquid portion of the oil at normal refrigerator temperatures. This property is undesirable where the oils are to be used for salad dressings and mayonnaise. This solidification of a portion of the oil or "graining" will break the emulsion of a mayonnaise made from it and cause the oil to separate from the other constituents.

To prevent the above condition salad oils are prepared by winterizing. The winterizing process consists of chilling the oil to a predetermined point and then filtering to remove the solidified portions. The oil is usually chilled in tanks which are located in refrigerated rooms, and the chilling may be aided by a refrigerant circulated through coils in the tanks. Also it is possible to prechill the oil going to the tanks by passing it through various types of heat exchangers. The rate of chilling and degree of agitation during the chilling and crystallization period are controlled in an effort to produce large crystal masses, which form a porous bed and allow easy filtration. In some cases the chilled oil is "seeded" by adding a few crystals from a previous batch. This seeding supplies nucleii for the growth of crystals, thus getting the graining started and promoting the growth of large crystal masses.

After crystallization has been completed, the mixture is pumped to conventional filters for separating the solid and liquid portions. It is desirable to use pumps which are gentle in action and do not break up the agglomerates of crystals which are formed during the graining process. As in the case of the chilling tanks, the pumps and filters are located in refrigerated rooms.

Hydrogenation

Development of the hydrogenation process had a far-reaching effect on the edible oil industry in this country (1). Besides improving the keeping quality of the fat, it made possible the production of solid shortenings without the use of lard, beef fat, or other naturally-occurring hard fats. Liquid phase hydrogenation applicable to fatty oils was developed by Normann early in the 20th century.

Most of the hydrogenation in this country is carried out as a batch process. The machines usually consist of closed cylindrical tanks built to withstand pressure and equipped with heating and cooling coils. Some machines are equipped with mechanical agitators while others depend on the entering hydrogen gas to supply the necessary agitation. In either case some type of distributor is used in order to insure good distribution of the hydrogen gas being bubbled through the oil.

In the hydrogenation process the oil is charged into the vessel and the catalyst, usually finely divided nickel, is added. A stream of hydrogen gas is turned into the machine, and heat is applied to get the reaction started. The reaction is an exothermic one, and it is necessary to cool the charge as it proceeds. Samples of the oil are withdrawn at intervals for determining its refractive index. When the predetermined desired refractive index is reached, the hydrogen flow is stopped, the charge is cooled and then filtered to remove the suspended catalyst.

At least one continuous hydrogenation process has been developed, but due to limited capacity and selectivity it has not been adopted in this country.

Hydrogen combines with the glycerides by entering at the unsaturated bonds in the carbon chain linkages of the fatty acids. This reduces the unsaturation of the fat and thus increases its resistance to oxidation. At the same time there is a rise in the melting point of the fat.

Selective hydrogenation depends to a large extent on the type of catalyst used, the activity of the catalyst, and the purity of the hydrogen gas. As used here, the term "selective hydrogenation" refers to the hydrogenation of the most unsaturated glycerides first and to the suppression of iso-oleic acid formation. Iso-oleic acid is a high melting isomer of normal oleic acid, and its presence gives a firmer fat at a given iodine value than does normal oleic acid.

Complete hydrogenation usually produces a fat too hard for use as shortening, and the consistency desired in the finished product determines the degree of hydrogenation. Naturally the shortening manufacturer strives for selective hydrogenation. For the sake of resistance to oxidation he likes to hydrogenate to as low an iodine value as possible without making his product too firm.

It might be of interest to mention here that the so-called solid shortenings usually contain only 10-18% solids at room temperature. The remainder is liquid oil. The solid portion forms a crystalline matrix and holds the liquid oil much as a sponge holds water.

The aim of the margarine producer is usually a little different from that of the shortening producer, and frequently he will use rerun catalyst which has lost some of its selectivity. This non-selective catalyst promotes the formation of iso-oleic acid which tends to give a texture and consistency nearer like butter.

The margarine manufacturer is willing to sacrifice some in keeping quality in order to obtain these other desirable properties of the product. During the past season the cottonseed oils in some areas have been so low in iodine value that margarine manufacturers have not been able to produce the desired amount of isooleic acid.

Formulation

It is possible to exercise some control over the keeping quality, consistency, and texture of a product by a choice of the oils making up the mix. Some oils naturally have better keeping qualities than others. Also two different oils, such as soybean and cottonseed for instance, will not have the same texture and consistency when hydrogenated to the same endpoint. With respect to the texture of hydrogenated shortenings it is usually desirable that fatty acids of several chain lengths be present in the glycerides. Thus, in the case of an oil in which C_{18} acids predominate, it may be advantageous to blend with this oil another which contains a relatively high percentage of palmitic acid.

The shortenings on the market today consist almost entirely of two types, the all-hydrogenated and the standard shortening. In the all-hydrogenated type all the oil is hydrogenated to some extent. In the standard shortening type unhardened oil is mixed with enough almost completely hydrogenated fat to give the desired consistency.

Deodorizing

The flavors of most vegetable oils before or after refining, bleaching, and hardening are too strong to be pleasing, and the oils require deodorization.

Eckstein carried out deodorization in the latter part of the 19th century by blowing high pressure steam through the oil (1). Wesson improved the process by using higher temperatures and maintaining the oil under vacuum while blowing with superheated steam.

Deodorization is a steam distillation where odor and flavor producing bodies along with small amounts of free fatty acids are distilled from the oil. The batch process is still largely used, and the operation is carried out in closed vessels holding 20,000 to 40,000 lbs. of stock. The vessels are usually equipped with heating and cooling coils although in some cases heat is supplied by circulating the oil through coils in direct fired furnaces and back to the deodorizing vessel. Where heating coils are used within the vessel, the necessary agitation is supplied by the blowing steam. High temperature and vacuum aid distillation, and the vacuum also protects the oil from oxidation by atmospheric oxygen.

The oil is charged to the vessel, the vacuum is pulled up to within a few millimeters of the barometer, and the charge is heated to about 450°F. The temperature, vacuum, and blowing steam are maintained for periods of 2 to 6 hours.

The time for deodorization will depend on the type of oil being processed and on whether a nearly bland oil or one having slight flavor is desired. The process should not be continued longer than necessary to produce the type oil desired. Some of the natural antioxidants, such as tocopherol, tend to distil over and the longer the deodorization period the more of these materials that are lost.

After deodorization is completed, the charge is cooled and filtered, usually through paper backed by canvas.

Several semicontinuous and continuous deodorizing systems have been developed and are currently in use. One of these continuous systems employs a tower in which the oil passes through a series of bubble trays, where it has intimate contact with the blowing steam.

Plasticizing

Some of the first vegetable oil shortenings were of a grainy type and similar in appearance to lard. The fat was either filled into containers in a molten state and allowed to cool and solidify, or it was chilled in tanks until crystallization began and then poured into containers where the crystallization and solidification were completed. In this type of processing the rate of chilling, the degree of chilling, and the amount of crystallization before packaging were variable, and this resulted in products of non-uniform texture and consistency. Until a few years ago one or two of these shortenings were on the market, and they may still be today.

Later the so-called lard roll came into wide use for the chilling of shortenings. This was a hollow cast iron roll about 4′ in diameter by 9′ long and mounted on bearings so that it could be revolved. The roll was chilled either by pumping brine through it or by direct expansion of ammonia into its interior.

In operation the roll was rotated, and during rotation its surface passed through a trough containing the molten fat. A film of fat adhered to the roll, and, in making almost a complete revolution on the roll, it was chilled to form a solid layer. This solid sheet of fat was scraped from the roll surface by stationary knives.

The sheet of fat dropped from the roll into what is known as a "picker box," which consisted of a trough in which there was a rotating shaft carrying a number of paddles or spikes. The purpose of the picker box was two-fold. It served to beat air into the product, which improved its appearance and texture, and it acted as a holding vessel in which crystallization was continued. While the sheet from the roll was usually solid, it was in a supercooled condition, and much of the crystallization remained to take place after the fat left the roll surface.

From the picker box the viscous fat was pumped under pressure and through a throttling valve to the container. The pressure and throttling improved the texture and appearance of the shortening by uniformly distributing the air bubbles within the fat and by breaking up any large agglomerates of crystals.

The use of the roll allowed the production of a reasonably uniform product. By varying the speed of the roll and the temperature of the refrigerant, it was possible to control the rate of chilling and the degree to which the fat was chilled. This will be discussed further a little later.

In the early 30's the Votator came into use for chilling fats. This machine consists of one or more nickel tubes, 3-4 in. in diameter, through which the fat passes. The tubes are surrounded by jackets, through which the refrigerant is circulated; and within each tube is a revolving shaft, which carries knife blades for scraping the chilled fat from the inside surface of the tube.

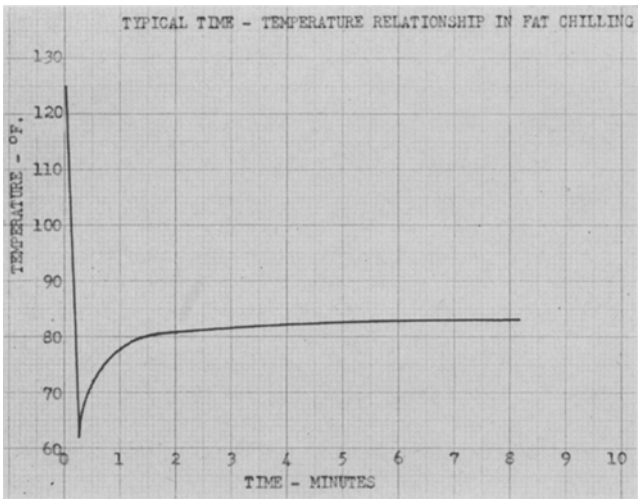

FIG. 1.

The molten fat is pumped to the Votator, and usually the air or inert gas to be incorporated is injected into the stream of liquid fat before it enters the Votator. Under normal pump pressure at least a part of this gas is dissolved in the liquid fat. The fat is chilled by contacting the inner surfaces of the refrigerated tubes, and the revolving knife blades continuously scrape the chilled fat from the tube surfaces. This scraping is necessary for maintaining a reasonable rate of heat transfer.

As the fat leaves the Votator it is cloudy, showing that some crystallization has taken place. However it is in a supercooled condition and is completely liquid at this point.

From the Votator the fat flows to the picker box. In this case the picker box is a closed vessel equipped with an internal shaft carrying paddles or spikes for agitation. The sole purpose of this picker box is to allow holdup time for crystallization to proceed to the desired point before the fat is filled into its container.

The fat flows from the picker box through a throttle valve and into the container; the throttling operation serves the same purpose as in the case of roll processing. With Votator operation a single pump can pick up the molten fat and supply the necessary pressure for flowing the material through the entire system and into the final package.

Margarine processing went through somewhat the same developments as shortening processing except that in the beginning it was chilled by flowing the molten fat into a vat of ice water or brine. The water was drained from the solid fat, and it was worked to give the desired texture and to incorporate flavoring ingredients. Roll processing and Votator processing followed. In present Votator processing it is customary to make an emulsion containing the fat, milk solids, other flavoring materials, and color. This complete mix is then processed through the Votator.

The advent of the Votator marked a distinct forward step in the processing of shortenings and margarines. It made possible a completely closed system where the fat is never exposed to the atmosphere from the time it enters the deodorizer until the package is opened by the final consumer. It also contributed to closer control of the chilling operation with the preparation of more uniform products.

The rate at which a fat is chilled, the degree of supercooling and the amount of crystallization taking place before the fat is packaged determine its crystalline structure. The crystalline structure in turn is responsible for the texture and consistency of the finished product. Figure 1 shows a typical curve for the time-temperature relationship in fat chilling. As the fat comes under the influence of refrigeration, its temperature drops rapidly and it becomes supercooled. When the fat leaves the field of refrigeration, its temperature begins to rise immediately due to the heat of crystallization. The rate of temperature rise is rapid at first and then diminishes as crystallization approaches completion.

The fat may be packaged at any time after it leaves the zone of refrigeration. If it is packaged soon after completion of chilling, it will set up and become firm in a matter of seconds. However such a fat will be relatively firm and will tend to be brittle and ribby in texture. If the fat remains in process in the picker box until practically all the crystallization has taken place, it will be relatively soft and the texture will be smooth, but it will take hours for it to set up enough for the packages to be handled. Usually the fat is packaged at some compromise between these two extremes.

In general, it may be said that a low chilling temperature and a relatively small amount of crystallization after packaging will tend to give a fat of soft consistency and smooth texture.

As stated above, the rate and degree of chilling have a marked effect on the crystal structure of the fat. Figure 2 is a composite photomicrograph. The

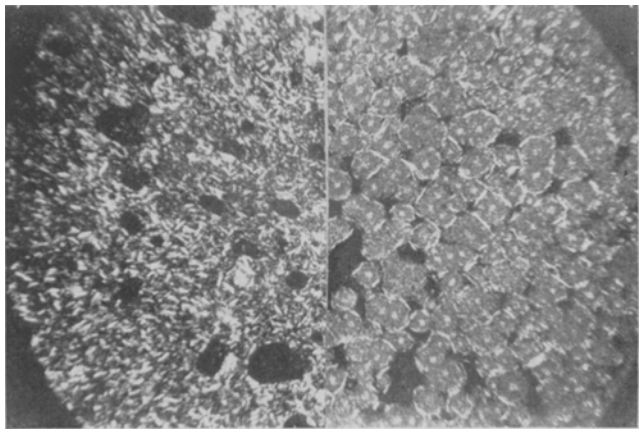

FIG. 2. Fat crystal structures.

left half shows the crystal structure of a nationally distributed shortening as it comes from the grocer's shelf. The right half shows the same fat after having been melted and allowed to crystallize and solidify at room temperature. These photographs were made by polarized transmitted light. Differences in crystal structure are not only evident under the microscope, but their existence can be demonstrated by x-ray diffraction patterns.

Tempering

The final step in processing shortening is the tempering operation. This consists of holding the packaged fat in a constant temperature room, usually 70 to 90°F., for a period of 2-3 days. Probably some additional crystallization takes place during this time,

and there is conversion of crystals from one polymorphic form to another. Variations in consistency and texture result if the fat is not tempered and is exposed to wide variations in temperature during the first 24-48 hours after the chilling operation.

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Some Factors Affecting the Hydraulic Extraction of Cottonseed Oil

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FOR the last four years the University of Tennessee has been engaged in a study to determine the effects of cooking and pressing variables on the residual oil content of cottonseed meal. The work has been done in the Engineering Experiment Station of the university under a contract with the Department of Agriculture. In addition to determining the effects of the processing variables on the amount of residual oil, recommendations were made to oil mill operators for the modification of their practices so that the potential additional oil yield could be realized.

A search of the literature on this subject revealed that very little information was available. In addition to Bailey's well known work (1), only two papers were found: one by Koo (2) and one by Baskervill and others (3). The results presented in these papers were not conclusive and, in some respects, were conflicting. They did however indicate certain trends which guided the experimental work.

Experimental Equipment

When the work was begun, the university was operating a pilot plant press room. It was soon found that it was impossible to control the variables satisfactorily on large scale equipment, and special apparatus was soon developed for the needs of the investigation. As finally set up, the equipment included a standard huller and five-high roll. The greatest change was made on the cooker. Instead of a stack cooker, or the pressure cooker which had been developed previously at the University of Tennessee, it was found necessary to use a small cooker composed of a glass jar immersed in an oil bath. Figure 1 shows the cooker disassembled. The meats were stirred during cooking by a rotating agitator with variously tilted blades attached as shown in the illustration. Projecting down from the cover of the jar were two other rods, which served to break up the meats adhering to the blades. One of these projections was hollow and served as a thermometer well for determining the temperature of the meats while cooking. The capacity of this cooker was approximately 500 g. of meats.

Because the meats were cooked at temperatures well above their surroundings, it was found necessary to heat the cooker lid in order to prevent heat loss by radiation. This was done by making the lid of a thick aluminum block and inserting two electric heaters as shown in the illustration. A reflux condenser was attached to the lid of the cooker so that the moisture content of the meats would remain unchanged while they were cooked at atmospheric pressure. Figure 2 shows the cooker assembled and operating in the oil bath. The oil bath was heated by a thermostatically controlled heater. A small propeller in the bath outside the cooking jar insured circulation of the oil and even distribution of temperature. By preheating the cooker lid, it was found possible with this equipment to raise the temperature of the meats from room temperature to 220°F. in approximately 15 minutes.

The presses used were standard Carver Laboratory presses arranged as shown in Figure 3. The pressing chambers were enclosed in jackets through which oil from a constant temperature reservoir was circulated for the purpose of maintaining a constant temperature in the cakes during pressing. It was found necessary to manifold the pressure chambers of these presses in order that pressure might be applied at the same rate in all presses simultaneously. The rate of application of pressure was found to be a critical factor in determining oil yield, and the desired uniformity could not be maintained by hand application of load to individual presses. Apparatus for determining moisture and oil content and other chemical tests was standard analytical equipment.

Since the tests were made on such small-scale equipment, it seemed desirable to make checks on a mill scale in order to establish the validity of the laboratory work. Such tests were accordingly made with the cooperation of the Perkins Oil Company at Memphis, Tenn. Figure 4 shows how electric strip heaters were placed in two grates of a standard box press so that one of the boxes might be heated from both above and below in order to maintain a pressing temperature at any desired level. Slots were milled in the grates to accommodate the strip heaters as shown. Figure 5 shows the heated grates inserted in a standard 15-box press with electric power connections attached.

A wide range of variables was investigated during the laboratory study. Cooking time ranged from 30 to 120 minutes and cooking temperature from 220° to 250°F. Pressing time ranged up to 2 hours, the total pressure varied from 2,000 to 4,000 lb. p.s.i., and the rate of application of pressure from 67 lb. p.s.i. per minute to 500 lb. p.s.i. per minute. Pressing was performed at temperatures of 140°, 170°, 210°, and 230° F. Hull contents were 29, 43.5, and 54%. Normally hull content is slightly less than 29%, but a lower value could not readily be attained with the equipment available in the laboratory. The cake moisture ranged from 4 to 15%. Cake thickness varied from ¼ to 2½ inches.

A standard cooking and pressing procedure was adopted for most of the tests. The meats were raised