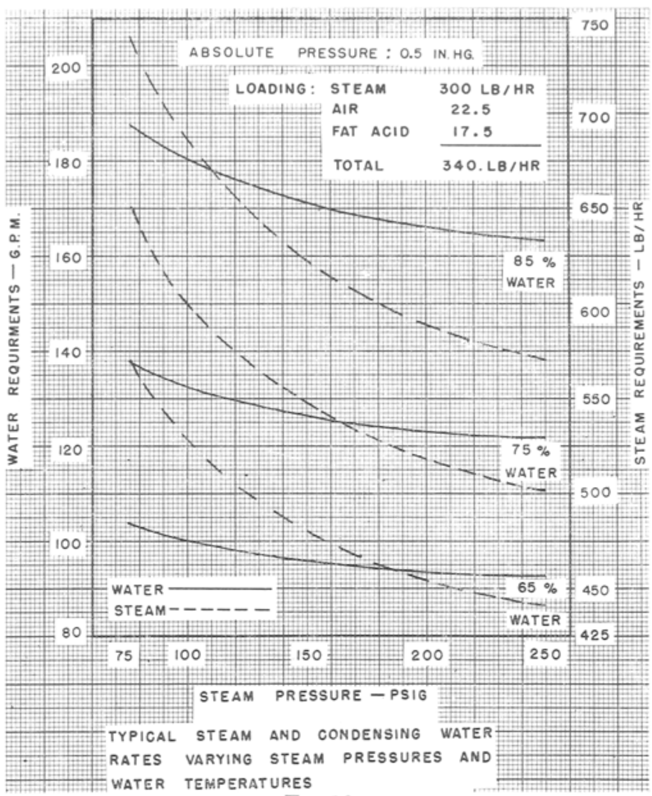

FIG. 16

has increased the flow area and produced a rough wall surface. The throat diameter of the diffuser and nozzle should be compared with the original sizes. If any scale deposits are found in the nozzle or diffuser, they should be carefully removed.

The operation of any deodorizer is naturally dependent upon continuous high vacuum. However it is not always the vacuum equipment which is faulty in case of either poor product, insufficient vacuum, or both. Air leaks should be found if they exist, and this can be done with a leak detector during operation (17).

An alternate means of locating leaks may be carried out when the deodorizing system is shut down. It calls for sufficient ammonia (from bottled gas or aqueous ammonia) to build up a pressure in the deodorizer system of about 1 p.s.i.g. The pressure is then raised to about 20 p.s.i.g. with air or inert gas.

All suspected points of leakage can be checked by passing a burning sulfur taper within about 12 in. of the point in question. If a leak exists, a white fume will form instantly, and it will seem to issue from the leak.

REFERENCES

1. Bates, R. W., J. Am. Oil Chemists' Soc., *26*, 601–606 (1949).
2. Morris, C. E., J. Am. Oil Chemists' Soc., *26*, 607–610 (1949).
3. Bailey, A. E., "Industrial Oil and Fat Products," Interscience (1951).
4. Baldwin, A. R., J. Am. Oil Chemists' Soc., *25*, 33–35 (1948).
5. Jamieson, G. S., and Baughman, W. F., J. Oil and Fat Ind., *3*, 347–355 (1926).
6. Spannuth, H. T., J. Am. Oil Chemists' Soc., *26*, 618–622 (1949).
7. Phelps, G. W., and Black, H. C., (to Industrial Patents Corporation) U. S. Patent No. 2,407,616 (1946).
8. Technical Bulletin No. 72, Citric Acid-Edible Oil, Chas. Pfizer and Co. Inc.
9. U. S. Patents 2,485,631 to 2,485,640 inclusive and 2,523,792 to The Best Foods Inc.
10. Schwab, Cooney, Evans, Cowan, J. Am. Oil Chemists' Soc., *39* (5), 177 (1953). (Editor. reference incorrect ? ? ? ? ?. ?)
11. Gearhart and Stuckey, J. Am. Oil Chemists' Soc., *32*, 386–390 (1955).
12. Thurman, B. H., (to Kraft Foods Inc.) U. S. Patent 2,621,196 (1952).
13. Lawrence, E. A., Chem. Eng. Prog., *48*, No. 5, 241–246 (1952).
14. Souders and Brown, Ind. Eng. Chem., *26*, 98–103 (1934).
15. Perry, John H., "Chemical Engineers Handbook," 3rd ed.
16. Processes Using Dowtherm, Bulletin ID-50-1, Foster Wheeler Corporation.
17. White, F. B., J. Am. Oil Chemists' Soc., *28*, 438–40 (1952).

Margarine Production

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MARGARINE PRODUCTION in the United States for the last 10 years has been at about an average rate of 1 billion lbs. per year. It is a big industry, a tremendous outlet for the products of American farms. It supplies jobs not only for those directly engaged in the production of margarine but also for those engaged in supplying the necessary equipment for that production. It supplies Mr. and Mrs. America with a nutritious palatable food at low cost.

L. C. Brown

Margarine was introduced into the United States according to Snodgrass in 1874 (1), after its invention in France by Mege-Mouries during the Franco-Prussian war of 1870. Figure 1 will show that the volume of the material produced grew slowly through economic and legislative trials spurting during World War I. The scarcity of fats in World War II and the economic desirability of producing margarine gave the American consumer the opportunity to become better acquainted with the modern version of this spread. The reaction of the consumer was favorable, ultimately resulting in the passage of a federal law permitting the sale of yellow margarine tax-free. This provided the impetus for greater growth of the industry, and margarine has retained its position since that time.

The improvement in quality of the product, while a gradual process, has been influenced most greatly by discoveries and inventions and through legislative enactments. If the history of margarine production in the United States is traced, there are certain milestones of progress, which are about as follows:

1. introduction from Europe of margarine made principally from fractionated beef fat;
2. the invention of the processes of alkali-refining, deodorization, and hydrogenation, making the use of vegetable oils possible;
3. development of the continuous closed system of crystallization and texturization, as illustrated by the Votator process;
4. standardization of the product through the promulgation of the standard of identity under the Food and Drug Administration; and

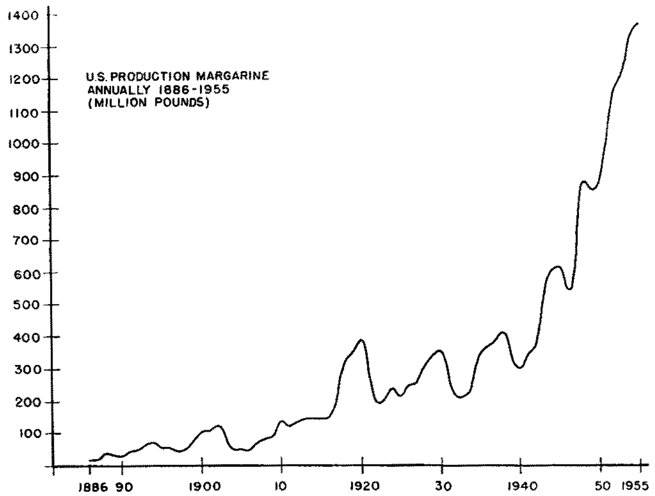

FIG. 1. Margarine production 1886-1955.

5. the Yellow Margarine Act of 1950, legalizing federally the use of yellow color in margarine on a tax-free basis.

There have been many other improvements in margarine history. Of nearly equal importance, for instance, were the development of selected strains of bacteria for culturing milk instead of natural souring; the use of coconut oil so predominant during the early 1920's; the development of modern emulsifying agents, such as mono- and diglycerides, which were so important in stabilizing the emulsion and permitting the manufacturer to standardize his product at 80% fat; the change from coconut oil to domestic oils, such as cottonseed and soybean; the developments of synthetic vitamin A, naturally extracted carotene, and synthetic carotene, and, last but not least, the utilization of dilatometry to control oil compositions leading to a more plastic type of margarine. All of these changes have had a marked effect on the entire industry. All were therefore important to the industry.

A description of margarine would not be complete without a reference to its nutritive quality. Since margarine is 80% fat, the nutrition it provides is primarily that of fat. The fat has a melting point approximately that of body temperature and is therefore nearly completely digested and is equal in this respect to any other fat of like melting point. Margarine in the United States is fortified with 15,000 U.S.P. units of Vitamin A per pound and is an important source of this dietary requirement. Margarine also contains substantial amounts of essential unsaturated fatty acids. Many margarines also supply 2,000 units Vitamin D per pound. It is possible that in the national diet the need for this nutrient may be supplied in the form of other foodstuffs, nevertheless the use of this fat-soluble vitamin makes margarine equal in food value in all respects with any other fatty food substance.

The position of margarine in the national diet as a food fat has been well established by statements of the Food and Nutrition Board of the National Research Council, the Council on Foods of the American Medical Association and its place in the basic seven food charts of the United States Department of Agriculture. Workers in the field of fat nutrition whose findings have led to the above conclusions are many. The outstanding work however of A. J. Carlson of the University of Chicago and the late Harry J. Deuel of the University of Southern California deserve special recognition. These two proved beyond doubt the equality of food value of the present-day margarine with other similar food fats. The scientific endeavors of these two men have been a big factor in acquainting the public with the true value of this product and its established high standing today.

A description of the production of margarine must consider raw materials, manufacture, process and product control, and sanitation. To keep pace with progress in the industry there must also be a research program.

Raw Materials. The raw materials for margarine are the oils, milk, salt, emulsifying agents, vitamins A and D, coloring materials, flavoring materials, and cultures. For the production of high quality margarine each of these materials must have certain definite characteristics and meet certain specifications.

The margarine industry during the year ending December 31, 1955, used 277,921,000 lbs. of cottonseed oil and 745,024,000 lbs. of soybean oil. The use of these two oils forms so great a part of the total oils used that they will be the only ones considered in this report.

There are certain physical characteristics of margarine which are largely determined by the character of the oil. These characteristics to a large extent determine the desirability of the product. They are flavor, texture, plasticity, and melting. Since the flavor of margarine is obtained through the use of cultured milk or artificial flavor or both, it is essential that the oil impart no flavor. This requires that the oil be deodorized to blandness and that it have sufficient stability to remain bland for a considerable period of time. The texture, plasticity, and melting characteristics of margarine are inter-related. All may be influenced slightly by processing in the margarine factory but are primarily determined by the characteristics of the oil. An ideal margarine would have good spreadability out of the household refrigerator, would have quick melting or quick solubility in the mouth for release of flavor, and at the same time would not melt or become unduly oily at normal room temperatures. At the present time margarine falls short of this ideal objective partly because of the trend in merchandising where the product is sold or displayed without the benefit of protection by refrigeration. Oils are therefore produced to withstand this treatment and accordingly have somewhat less than the desired melting in the mouth characteristics.

Over the years there have been many attempts to devise analyses of the liquid oils and predict the consistency characteristics of the solidified fat. These have included various melting-point determinations, congeal-points, cloud-points, titer of the fatty acids, and so forth. When used in combination, a fair job of predicting consistency could be made. In recent years a new measuring tool has come into use, that of dilatometry, the determination of the ratio of solids to liquid fat at any given temperature usually reported as the solids content index. This determination appears to be a step forward in pre-determining from the liquid fat the consistencies which will be obtained in the finished product (2). A good explanation of the determination is given by Fulton and co-workers.

At the present time in the production of margarine oil from cottonseed and soybean oils a choice must be made whether one wants to have good melting characteristics in the mouth or to suffer in this respect but to achieve improved plasticity and improved stability at high store temperatures. The first type is illustrated by solids content index curves 1 and 2 of Figure 2 while the second type is shown by curve 3. Curves 1 and 2 are soybeean oil and cottonseed oil, respectively, selectively hydrogenated. Curve 3 represents a blended margarine oil.

It will be noted that margarine oil prepared from cottonseed oil has a lower solids content index at the low temperature end of the curve, indicating better spreadability than soybean margarine oil. It was the economic desirability of using large amounts of soybean oil and developments minimizing flavor reversion tendencies of this oil which led to the use of blended formulas. These permit the use of large quantities of this oil without undesirable brittleness at low temperatures. Blended formulas also obtain

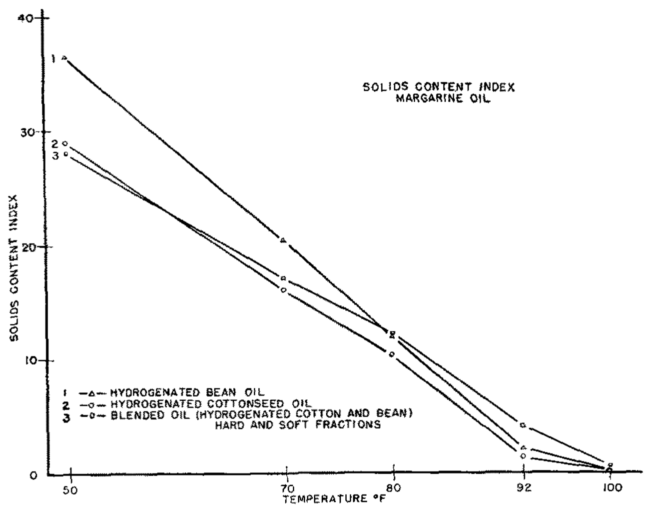

FIG. 2. Solids content index curves three types margarine oil.

stability at high temperatures, which is evident from an examination of the high temperature end of Curve 3. The principle involved is that of blending two or more fractions of oils of varying degrees of hardness obtained through hydrogenation. The curve shown is that of a simple blend of two fractions, one consisting of 17% of the total hydrogenated to an iodine No. of 54.0 and the remaining 83% hydrogenated to an iodine No. of 88.0.

Figure 3 illustrates the solids content index curves of fat extracted from six leading brands of margarine.

The Standard of Identity permits the use of cream, milk, skim milk, reconstituted dry milk solids, or a combination of any two or more of these articles. Nearly all of the margarine produced in this country is prepared from either fresh liquid skim milk or re-constituted non-fat dry milk solids. Specifications for these two materials are shown on Figure 4.

The specifications for salt should require high purity, practically free from copper and iron, less than $\frac{1}{10}$% calcium and magnesium, essentially free from non-soluble material, with a high solution rate (3).

Mono- and diglyceride emulsifying agents should contain at least 40% monoglycerides and be sufficiently bland in flavor that double the amount contemplated for use will not affect the flavor of the oil to which they are added.

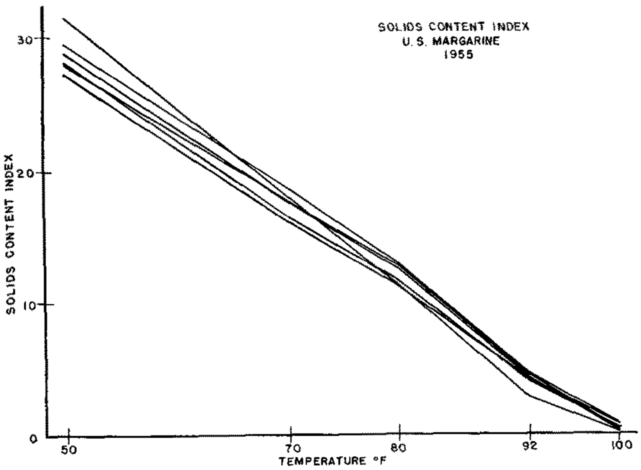

FIG. 3. Solids content index curves of fat extracted from six brands of margarine.

Lecithin is added to margarine to prevent spattering when used as a frying fat and should first of all be satisfactory in this respect according to tests. It should preferably be of the free-flowing type for easy handling, should be completely fat-soluble, should be not less than 60% acetone-insoluble, and should not affect the flavor of the oil when double the amount contemplated for use is added.

Vitamin A may be from several different sources, such as a natural extract of marine liver oils or a derivative of these. It may be synthetically produced, or it may be a blend of natural and synthetic. It has been determined that the ester form of vitamin A has superior stability to the alcohol form and is therefore preferable to use. Vitamin A concentrate should not affect the flavor of the margarine when at least double the amount contemplated is used.

Vitamin D for margarine is usually the synthetic form of irradiated or activated ergosterol known as vitamin D_2. It is available in oil solution in a highly concentrated form. It should assay to meet the guarantee of the supplier, and it should not affect the flavor of the margarine when double the quantity contemplated is added.

There are several different commercial artificial coloring substances available. Food, Drug, and Cosmetic certified colors numbers 3 and 4 are fat-soluble aniline dyes. Food and Drug certification is usually sufficient specification. There are several types of color concentrates made from the annatto seed. One is an oil-soluble extract. Another is a chemical derivative, ethyl bixin, in which the ethyl ester of bixin

MARGARINE MILK SPECIFICATIONS

NON FAT DRY MILK SOLIDS A.D.M.I. STANDARD FOR* EXTRA GRADE SPRAY TYPE		FRESH FLUID SKIM MILK
	NOT GREATER THAN	
BUTTER FAT	1.25 %	TITRATABLE ACIDITY MAX. 0.18 %
MOISTURE	4.00 %	TOTAL SOLIDS MIN. 8.5 %
TITRATABLE ACIDITY	0.15 %	*METHYLENE BLUE REDUCTION TIME MIN. 5 1/2 HR
SOLUBILITY INDEX	1.25	BACTERIA TOTAL PLATE COUNT MAX. 200,000/ML
BACTERIAL ESTIMATE	50,000/GM	*SEDIMENT A.P.H.A. STANDARD DISC MAX. 1 MG
SCORCHED PARTICLES DISC B	15.0 MG	FREE FROM PRESERVATIVES, NEUTRALIZERS, OBJECTIONABLE FLAVOR, ODOR AND COLOR
FREE FROM LUMPS AND STORAGE OR SCORCHED FLAVOR AND ODOR		

FIG. 4. Specifications for fresh liquid skimmed milk and non-fat dry milk solids.

is the coloring principle. A third derivative is obtained, involving the process of converting natural red bixin to a yellow form by treatment with glacial acetic acid and acetic anhydride (4).

Beta carotene as a dispersion of micro-crystals in fat may be obtained either as naturally derived from carrots or as the pure synthetic material.

In the case of both natural beta carotene and synthetic beta carotene a dual function exists. Not only color but pro-vitamin A is supplied.

Purchase of annatto and annatto derivatives should be standardized on the basis of color supplied per unit amount of the coloring substance, and the two types of beta carotene should be purchased on the basis of their vitamin A equivalents.

According to the standard of identity, the artificial flavoring diacetyl may be used as such or as starter distillate. Accordingly purchases of artificial flavors should be in terms of diacetyl. It may be purchased either in the pure form or in the form of a starter distillate. When purchasing starter distillate, it should not only be bought on the basis of diacetyl content but upon the flavor achieved, which will undoubtedly be as a result of the balance of other naturally produced materials in the starter distillate with the diacetyl. Other than an analysis to maintain a standard diacetyl content the user must satisfy himself with the results obtained.

Last but not least in the materials to be purchased is a suitable lactic acid-producing bacterial culture. These are usually blends of more than one strain of *S. Lactis* with associated flavor-producing organisms. They may be purchased from several reputable suppliers in this country as well as in Europe and must be tested for satisfactory results from the standpoint of flavor. It should be determined bacteriologically, of course, that no contaminating organisms are present in the purchased cultures.

Manufacturing Processes. The margarine manufacturer buys oils to specification that require no further processing. The first step in his manufacturing process is usually that of treating the milk in order to make it ready for blending with the oil. If dry non-fat milk solids are to be used, they must be reconstituted. If fresh fluid raw skim milk is used, it must be pasteurized. Reconstitution of non-fat dry milk solids of the low-heat spray type is a very simple procedure involving the adding of the required amount of solids to the water preferably at a temperature of 100° to 120°F. with simple agitation, such as is found either in the coil type of pasteurizer or the vat type with vertical sweep agitator.

Pasteurization of either the fluid skim or the reconstituted skim may be carried out in vat pasteurizers by holding at 155°F. for 30 min. They may also be pasteurized through the so-called continuous plate-type pasteurizers reaching a temperature of 175° to 190°F. as desired, where it is maintained in the holding tube for a period of 15 seconds at that temperature. The latter type of pasteurizer is an efficient heat exchanger with a greater economy of operation than the vat type.

If the milk is to be cultured, it must be cooled to the desired temperature which is usually between 60 and 70°F., depending principally upon the length of time desired in the culturing operation. If the milk is to be used in the product without culturing, it may be chilled to 40°F. or below and held for use.

There are many different methods of culturing milk for use in margarine or, for that matter, in other products. The book "Margarine" by A. J. C. Anderson (1954) covers this subject very adequately and in detail not permitted by the scope of this paper. One time-honored method, however, which is simple in operation, is the following:

Fresh, fluid, whole, or skim milk is placed in quart-size milk bottles or heavy 1-liter Erlenmeyer flasks capped with several thicknesses of parchment paper and sterilized either by Autoclaving at 15 lbs. pressure for 15 min., or by placing in flowing steam for 1 hr. The bottles are then cooled to 70°F. and are ready for inoculation. If a commercial culture in a dry form is to be used, it is thoroughly distributed in the milk, taking care to avoid possible contamination during the addition. The bottles are recapped and placed at 70°F. for 24–30 hrs. Using this material as an inoculum, new bottles of milk treated in like fashion are inoculated with about 1 to 3% of the material. These again are cultured at 70°F. for 24 hrs. and the process is repeated. After three such propagations the mother culture should be ready for use as inoculating material for the larger intermediate cultures. It may also be used to re-propagate additional mother culture. New mother cultures should be prepared about every two to three weeks. The larger intermediate cultures are prepared by filling 10-gal. stainless steel cans equipped with an overlapping, tight-fitting cover, with sterilized fluid, skim, or whole milk or reconstituted non-fat milk solids in which the sterilization process is carried out by heating at 180 to 190°F. for 1 hr. The milk is cooled to 70°F., and a 1-qt. bottle of the previously prepared mother culture is added and thoroughly distributed. Intermediate cultures are placed at 70°F. and allowed to stay at this temperature until the acidity of the milk has developed to at least .8% lactic acid and set to a rigid gel. It is then placed at 32°F. and allowed to chill before use as an inoculum for the larger vats of milk.

After the intermediate culture has cooled, it may be examined again for acidity and flavor and, if satisfactory, will be ready for use. The batch milk to be cultured is at a temperature of 60 to 70°F., and from 1 to 5% of the intermediate culture may be added and thoroughly distributed by the use of the agitator in the culturing vat. It is then allowed to ripen until the acidity desired by the user is obtained. This will usually vary from low percentages, such as .4 lactic acid for the production of mild margarine, up to .7% or even .8% for the production of high flavored margarines.

If it is desired to produce relatively greater quantities of diacetyl or acetoin in the culture, a few tenths per cent of citric acid or salts of citric acid may be added to the milk prior to culturing, or if a concentrate is desired, citric acid may be added to the culture after the acidity has reached .8 and allowed to ripen further at 70°F. or below. It has been shown that the production of diacetyl and acetoin is considerably greater under these conditions. This type of high-flavored culture may either be used as the source of starter distillate or may be blended with more lightly cultured milk for flavor increases.

Emulsions are made by several different techniques and under varying conditions that produce somewhat different results. According to Clayton in his book "Colloid Aspects of Food Chemistry and Technology," emulsions of the oil in water types are desirable and should be produced by running the oil slowly into the milk with vigorous agitation. This extreme is matched by the extreme of adding the milk slowly to the oils with vigorous agitation to produce an emulsion of the water-in-oil type. In addition to these two extremes, other methods of producing emulsions are as follows:

1. Half of the oil required for the batch and all of the milk are agitated vigorously for a few minutes, then the remainder of the oil is added with less vigorous agitation.
2. A half-batch is made, using method 1 and adjusting the emulsion temperature to about 90–95°F. To this is added a sufficient amount of cold milk (38–42°F.) for another batch of equal weight, with vigorous agitation until an emulsion of the desired characteristics is obtained. Then the remainder of the oil necessary to complete a batch is

added. In order to continue the sequence, only half of the material is drained from the emulsifying vat into the Votator, and the process is repeated for the subsequent batches.

3. The oils and cold milk are run concurrently to the emulsifying unit, and the timing of the addition is such that all of the milk for the batch is in the emulsifying unit by the time one-fourth to one-half of the oil is added.
4. The method described by Anderson in his book on margarine is one in which an initial emulsion is made with the higher melting point fraction of a blended oil type of margarine with all of the milk. After this emulsion is made, the lower melting-point fraction is added with the idea that the subsequently solidified emulsion will consist of nuclei of harder fat with an outer coating of softer fat, thereby improving the melting-in-the-mouth characteristics.
5. The continuous method of emulsification is carried out by proportioning a flow of oil and a flow of milk in the proper ratio to the Votator in which emulsification and chilling are carried out concurrently.

We are sure that there are also other techniques employed by manufacturers which may be variations of those mentioned above and by which the manufacturer feels he obtains some special benefit. The milk used in preparing emulsions generally is kept at comparatively low temperatures, usually between 32 and 40° F. The salt may be dissolved in the milk just prior to emulsifying. The oils are usually added at a temperature so that the final emulsion temperature will be somewhere near the melting point of the oil. The lecithin, mono- and diglycerides and other oil-soluble additives may be added to the oil before emulsifying. As the temperature of the oil is lowered, crystal nuclei form in the emulsion, the viscosity of the oil increases, and heavy emulsions are produced. With ordinary agitation there is also a tendency to whip air into the emulsion at low temperatures, much as cream is whipped, which also will tend to increase the viscosity of the mix. At higher temperatures the emulsion remains quite fluid, similar to the manner in which the oil from which it is made would behave.

As a general rule, conditions which tend to promote oil-in-water emulsions, such as the adding of the oils to the milk or that of producing crystal nuclei of the oil by low temperatures, will tend to produce improved melting-in-the-mouth characteristics. These characteristics also tend to produce improved flavor through quicker release of the milk and salt in the mouth. Higher temperatures of the oil produce emulsions with better handling characteristics and with less occluded air, resulting in easier control of weights at the print machine but, in our opinion, with a lesser degree of flavor and somewhat poorer texture.

We believe that nearly all margarine made in the United States today is chilled or crystallized by the Votator process. The Votator is an internal chilling machine, as contrasted to the chill roll which the Votator superseded. The Votator chilling unit is constructed usually of one or more jacketed tubes or cylinders. The refrigerant, usually liquid ammonia, flows through the jacket, and the emulsion is pumped through the tube, being continuously removed from the chilling surface by rapidly revolving scraper blades. The result of simultaneous agitation and rapid chilling is super-cooling. The emulsion emerges from the chilling unit in a liquid condition cooled substantially below the normal solidification point. When agitation or fluid motion is stopped, or markedly slowed down, crystallization of the fat takes place and the product sets very rapidly. The crystallization phase in the Votator process takes place in a tube of sufficiently larger diameter to slow down the flow of the super-cooled product. This tube is called the B Unit, and the product is forced through it directly from the chilling unit. The chilling tubes are known as the A Unit. The discharge end of the B Unit is equipped with a perforated plate or screen from which the product emerges as noodles or ribbons ready for print-forming.

The Votator has become so universal in its operation for the production of margarine that little need be said concerning the specific methods of operation. An excellent description however is found in the proceedings of the six-day short course of 1948 sponsored by the American Oil Chemists' Society. The author is J. E. Slaughter Jr., Votator Division, Girdler Corporation, Louisville, Ky.

The next step in the production of margarine is packaging. Nearly all of the margarine produced in this country is packaged in the form of quarter-pound sticks, four to a 1-lb. package. Nearly all margarine is produced by the continuous Votator chilling method with a continuous quarter-pound print-forming machine operating directly in connection with the cartoning machine. From an operating standpoint there is little that can be said about this machine. However, for good continuous operation, the margarine must be sufficiently firm so that it will not smash, resulting in machine-jamming with loss of time and subsequent inconvenience. In this respect the ability of a print-forming machine to operate properly has often been the limiting factor in formulating margarine. A product soft enough for best eating quality could not be formulated since it could not be printed directly from the Votator in an over-all continuous process. This is fundamentally an error since the chief factor in formulating margarine should always be the end-usage of the product, such as palatability or spreadability, rather than the operating requirements of a machine. A general idea can be obtained regarding the printability of a particular formula through an examination of the solids content index of the formula. An average temperature of printing rooms and of product at the time of printing would be about 70°F. Continuous printing can be carried out with a formula having a solids content index at this temperature of as low as 16. Better results from the standpoint of less likelihood of machine-jamming are obtained with higher solids content index on the order of 18–19, and it has been said that the ideal solids content index for this temperature would be 21 in which case, of course, continuous printing could readily be obtained.

The print-forming and packaging units are usually component parts of an integrated machine. The print as it is removed from the mold is thrust into the parchment or foil wrapper, the wrapping operation is completed, and the four wrapped quarter-pound sticks are assembled and either cartoned or over-wrapped by a secondary part of the machine. With the passage of the yellow margarine law, margarine has been an example for modern packaging and has shown the way for many food products. The styles of packages since that time have embraced such varieties as parchment-wrapped quarter-pound sticks over-wrapped in transparent cellophane, parchment-wrapped quarter-pound sticks in waxed cartons overwrapped with cellophane, foil-wrapped quarter-pound sticks in a waxed carton both solid and with a window displaying the foil-wrapped contents, and more recently, foil-wrapped quarter-pound sticks in a light-weight cardboard carton with a sealed foil over-wrap. The use of foil both on the quarter-pound sticks and as an over-wrap, has conveyed to the consumer the idea of preserving the freshness of the product.

After packaging, the product is sometimes shipped directly to the customer's warehouse but more often transported into a storage room. Some manufacturers in addition temper their product before placing in low temperature storage. Tempering of the product at temperatures from 75–80°F., until the internal temperature of the product reaches at least 75°F., will produce uniformity of consistency between packages of the printed product and to a certain extent will improve the plastic range. We have found that tempering produces marked improvement in the reduction of consistency as measured by a consistometer at 55–60°F. When the consistency of the same product is measured at temperatures from 32–40°F., the improvement in consistency is much less, with very little benefit being derived in tempering. However, in the course of forming quarter-pound prints from either noodles or ribbons of product emerging from the Votator B unit, there may be considerable variations in consistency even in the same quarter-pound sticks. Tempering will certainly benefit in that it will greatly improve the uniformity in this respect.

If it is desired to store the margarine for any length of time, such storage should be carried out in clean rooms free from harmful odors and at temperatures below 40°F. We have frequently heard it stated that margarine must not be carried at lower than freezing temperatures. Tests that we have conducted have not borne this out, and we have carried test product at temperatures as low as minus 30°F. for periods of several months with nearly perfect preservation and with no harm resulting to the product.

Process and Product Control

The manufacture of margarine should not be attempted without some degree of process and product control, either through instrumentation or through actual analysis. Raw materials must be tested to determine whether these materials meet the buying specification. If emulsification is carried out by the batch process, each batch should be checked for fat content and for salt content. If continuous methods of emulsification are employed, samples should be taken at frequent intervals for the same determinations. Fats should be controlled as close to 80% as possible without going below the 80% fat required by law. Statistical studies of variables permit close control on this point. Again, statistical analyses will indicate the frequency of chemical analyses required for close control. The finished product should be checked frequently for color, flavor, consistency, and vitamin A content. If pre-mixes of vitmain A with oil, or possibly with oil and coloring substances, are used, analysis of this pre-mix for vitamin A content may be made for control purposes, permitting less frequent analysis of the finished product. Again, a study of the degree of variation will determine the frequency of analyses required.

Sanitation. It is unnecessary to say that margarine production must be carried out in a clean, sanitary establishment. Margarine is a perishable product and is of a sufficiently delicate nature to be easily affected in flavor and odor by contamination with harmful substances. The sanitation methods employed in the margarine factory are of the same general type as those used by dairy plants. An excellent paper on the subject was presented at the 1956 meeting sponsored by the Technical Committee of the National Association of Margarine Manufacturers (5).

In general, we believe there are four basic principles involved in maintaining a sanitary establishment.

1. Building construction and equipment layouts. Buildings must be constructed to provide adequate ventilation yet at the same time be tight enough to prevent access of rodents, insects, or dust. Wall surfaces should be smooth, and the junction of walls and ceilings should be tight and free from cracks. Floors should be provided with adequate drainage. The layout of equipment should be such that congestion is avoided and operations are well above floor level with a minimum of locations where adequate cleaning cannot be obtained.
2. Housekeeping. Housekeeping must be clean and orderly as exemplified by the slogan, "a place for everything and everything in its place."
3. Cleaning schedule. The best sanitation practices include a regular cleaning schedule for equipment as well as regular janitor service for floors, ceilings, walls, etc. The cleaning schedule for equipment should provide for daily cleaning of milk-holding tanks, milk pasteurizers, sanitary lines for handling milk as well as emulsifying units and lines to and from pumps transmitting emulsion through the Votators. Votators should also be flushed daily. Cleaning can be either by disassembling line and pumps or may be by cleaning in place. Cleaning in place is carried out by circulating cleaning solutions from a suitably located holding-tank through lines, pumps, and equipment and back again to the holding tank. When cleaning in place is employed, milk lines, emulsion lines, and pumps should be disassembled for additional cleaning at least once per month.
4. Sanitation Surveys. Frequent periodical sanitation surveys should be carried out in order to evaluate the cleaning schedule program. These surveys should include bacteriological plate counts of swabbings taken from critical areas in equipment, and of walls, ceilings, or any area near processing which might be a possible source of contamination. In addition, raw materials should be checked bacteriologically as well as finished products. Monthly surveys of this type are not considered to be too frequent.

Research Program. Like other modern American concerns, a company engaged in manufacturing margarine must carry on research if it is to keep abreast of competition.

We believe present-day margarine is a fine food product, providing the purchaser with a good bargain for every pound sold. We also believe that there is still plenty of room for improvements. We think the palatability of the product may still be improved as well as other characteristics, such as spreadability and keeping quality. We also believe that, as glamorous as the present packages are, newer packages will appear, representing further improvement. These over-all improvements will require basic research in the chemistry of fats and physical structure of the product as well as imagination of the package designer.

We have tried to cover the major points concerned with the production of margarine in a fashion that would give those unacquainted with the product some idea of what is necessary for production. For those already familiar with margarine production we are hopeful of providing a stimulus to more thought and more research. We are very glad to see more literature appearing on the subject of margarine, especially new books on the subject such as that by Anderson, previously referred to, and that by M. K. Schwitzer, just recently announced. We feel that there has been a dearth of literature on this important subject and that these books will be a very valuable contribution to the field of food technology.

REFERENCES

1. Katharine Snodgrass, "Margarine as a Butter Substitute," Stanford University Press, 1930.
2. Fulton, N. D., Lutton, E. S., and Wille, R. L., J. Am. Oil Chemists' Soc., *31*, 98–103 (1954).
3. Simpson, R. A., and Page, John M., "Salt as a Margarine Ingredient," Report of the Second Margarine Research Symposium, 1955, sponsored by the National Association of Margarine Manufacturers.
4. Cartwright, K. L., "Natural Plant Pigments for Margarine Coloring," Report of the Second Margarine Research Symposium, 1955, sponsored by the National Association of Margarine Manufacturers.
5. Fitch, K. A., "Sanitation," Report of the Round Table on Margarine Production ,and Handling, 1956, sponsored by the National Association of Margarine Manufacturers.

Finishing and Packaging of Edible Fats

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Theoretical Considerations

Definition and Description of "Plasticity." A solid exhibiting plastic properties may be defined as one which appears to be rigid when subjected to limited deforming stress, yet when the deforming stress increases beyond the yield point, it flows considerably like a viscous liquid. In the case of plastic fats Bailey (1) has described three essential conditions.

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1. There must be two phases, one a liquid, and the other a solid.
2. The solid phase must be finely dispersed to the extent that the mass is held together by internal cohesive force.
3. The two phases must be present in the proper quantities.

If solids are deficient, not enough crystals are present to hold the liquid oil entrapped in the lattice of crystals. If liquid is deficient, the fat is brittle and will tend to break rather than flow when deforming stresses are applied beyond the yield point.

The Structure of Plastic Fats. The photomicrograph shown here (Figure 1) exhibits the structure of a plastic fat. It consists of very fine discrete crystals, no more than a few microns in length, forming a lattice work in which liquid oil is entrapped and held there by surface tension. The large cells you see are the air cells incorporated in this commercial shortening. Plastic fats at the temperature at which they are normally used usually contain from 10 to 30% of solids. This fairly wide range is the result of differences in formulation. The two most important factors governing the consistency of a plastic fat are the number and size of the crystals and the viscosity of the liquid.

The Effect of Glyceride Composition. The commercial plastic fats are made up of a mixture of glycerides which, individually, melt at widely varying temperatures. This range will be from about —40°F. to about 150°F. for the highest melting component. This mixture gives a satisfactory plastic range, with the average melting point just a few de-

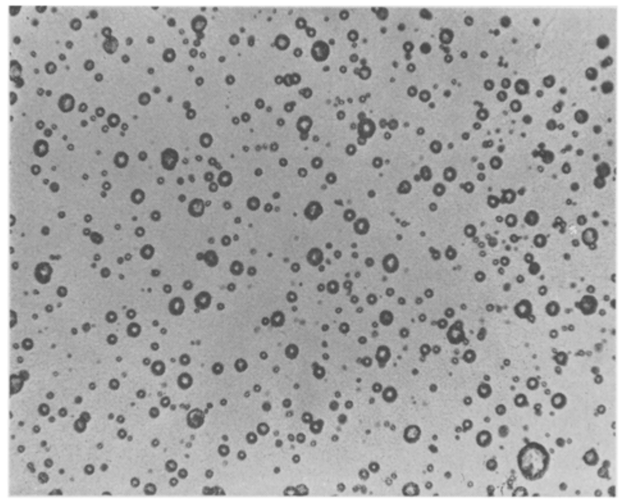

FIG. 1. Photomicrograph of a plasticized hydrogenated oil shortening (100 × at microscope).
Courtesy, Research and Development Division, Lever Brothers Company.

grees above body temperature. A satisfactory plastic range may be defined as a range of temperature at which the fat may be used with good results.

Fats which have sharp melting points consist of glycerides in which the saturated portion consists largely of a single class. Examples of this type of fat are cocoa butter and coconut oil. Under certain conditions of hydrogenation other vegetable oils may approach this behavior, for example, margarine oil, so hydrogenated as to have a high percentage of solid unsaturates, commonly known as iso-oleic acids. This imparts the desirable quick melting in the mouth to release milk flavors in the product.

Interesterification, or rearrangement of a mixture of glycerides, has an important effect on the consistency of the plasticized product. This is a subject of such scope that it can only be mentioned here. Consider the fact that a mixture of triglycerides will usually contain stearic, palmitic, and unsaturated fatty acids, then in a truly randomly distributed fat the distribution of the fatty acid radicals will be in accordance with the law of probabilities, based on the percentage of each component. Many natural fats, notably lard, do not have such random fatty acid distribution. The effect of random rearrangement in lard is to improve its plasticity and baking properties. Ordinary lard has the property of