Grasas y Aceites
Vol. 46 Fasc. 6 (1995), 357-365

Technical paper

Formulation of soy oil products*

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RESUMEN

Formulación de productos de aceites de soja

El trabajo presenta diferentes formulaciones a base de aceite de soja tales como aceites para ensalada y cocinado, margarina, grasas sólidas (shortenings), grasas sólidas comerciales, grasas sólidas para frituras y grasas fluidas. Hace también referencia al proceso de hidrogenación y a sus efectos en los productos finales.

PALABRAS-CLAVE: Aceite de soja — Formulación de productos — Información tecnológica.

SUMMARY

Formulation of soy oil products

The paper comments different formulations of soy oil products such as salad and cooking oils, margarine, shortenings, commercial shortenings, frying shortenings, and fluid shortenings. Hydrogenation and its influence on final products is also included.

KEY-WORDS: Formulation of products — Soybean oil — Technical paper.

Soybean oil is among the most versatile of all edible oil raw materials. It is used as the only or major ingredient in every type of edible oil product. It's high degree of unsaturation makes it suitable as a salad oil and also provides wide latitude for controlled hydrogenation to make all types of shortening, margarine and specialty food fats. In recent years it has even been used successfully in cocoa butter substitutes, a use previously dominated by coconut and palm kernel oils.

1. SALAD AND COOKING OIL

Soy oil is widely used as a premium oil for cooking and salads. In its natural state, it is highly unsaturated and an excellent source of the essential fatty acids linoleic and linolenic. Functionally it is a natural "winter" oil - that is - it will not crystallize when held at low temperature. This property is important when the oil is not used in making emulsions such as mayonnaise and salad dressings, since precipitation of fat crystals can cause separation of the emulsion. The property is measured by a standardized "cold test", procedure, consisting of immersing a sample in an ice bath and observing the number of hours before it begins to cloud. The generally accepted minimum standard is 5 1/2 hours. A fully refined soy oil containing no hydrogenated fat will have a cold test of 48 hours or more. From a practical standpoint there appears to be no particular advantage in extremely long cold tests, so commonly a specification of 15 hours is considered adequate as a control measure.

Soy oil is the vegetable oil most used by U.S. food processors. It is the principal ingredient in mayonnaise and salad dressing. These products are defined by FDA standards of identity and must contain specified minimum quantities of salad oil, as follows: Mayonnaise 65%, spoonable salad dressing 30%, French Dressing 35%. In addition a host of non-standard pourable dressings use significant quantities of oil.

Other commercial uses include bread, canned fish, pan grease and doughnut mixes.

Soy oil is the most widely used bottled oil or household use.

A principal objection to the use of natural soy salad oil was that it was considered to be more subject to flavor reversion than competitive oils. This tendency was associated with the linolenic acid content of the oil. As a result, processors adapted the practice of hydrogenating and winterizing the oil to make a more stable oil with greater resistance to flavor reversion. In this process the oil was hydrogenated to an iodine value of about 110 which reduced the linolenic acid to less than 3%. The oil was then "winterized" to remove the higher melting fractions created by hydrogenation. Until recently all of the major brands of soy salad oil marketed in the U.S. were the hydrogenated - winterized type.

However, it has been recognized for some time that natural soy oil processed by the best modern techniques it highly resistant to flavor reversion. About two years ago the formulation of one of the leading brands of household oil (Wesson Oil) was changed from the hydrogenated-winterized product to the natural unhydrogenated product. This has had excellent acceptance. It is my belief that there will be an increasing trend toward the greater use of the unhydrogenated oil for household use.

The hydrogenated-winterized product does offer greater stability and for this reason is preferable for some uses where the oil is subjected to abusive conditions such as repeated use in deep fat frying. However, the natural product is suitable for a majority of uses requiring liquid oil.

Several additions may be used in soy oil for commercial or household use. Citric acid is commonly added to all deodorized oils as a chelating agent to inactivate any trace metals which may be present. Polysorbate 60 or other emulsifiers may be added in small quantities to aid emulsification in salad dressing. Antioxidants may be added to improve shelf life. TBHQ is the most effective but BHA, BHT or Propyl Gallate may also be used. Methyl silicone may be added to improve resistance to breakdown in deep fat frying. Oxystearin or polyglycerol esters are added to hydrogenated-winterized soy salad oil as crystal inhibitors to improve cold test — they are not required in the natural product.

In addition to use as a liquid oil, soy oil can be used to formulate a variety of plastic or solid fats which are generally termed shortenings or margarines. Such fats may be made by blending liquid oil with a natural hard fat such as palm oil or beef tallow, or more commonly and with more flexibility and precise control, by hydrogenation of the soy oil under carefully controlled conditions.

Fats and oils provide a number of basic functional characteristics to food products (Table I).

Table I
Basic functional characteristics of fats and oils in food products*

THEY PROVIDE:	LUBRICITY
	STRUCTURE
	AERATION
	MOISTURE BARRIER
	HEAT EXCHANGE MEDIA
	NUTRITION
	CARRIER OF VITAMINS/FLAVORS/COLORS

*IMPOSED VARIABLES ARE FLAVOR AND FLAVOR STABILITY

Cochran (1975)

The importance of these functions vary for different types of food. As can be seen from this chart (table II) lubricity is universally desirable in all foods since it imparts smoothness and tenderness and adds richness and improved eating properties. In order for a fat to provide lubricity it must be melted, that is liquid at body temperature.

Other functions, namely, structure, aeration and moisture barrier depend upon the fat containing solid portions, at the temperature of use. The relative importance of structure, aeration and moisture barrier differs in different food products.

Margarine and vanaspati depend upon the fat structure to maintain the desired consistency traditionally associated with the product from the point of manufacture to the point of consumption and then melt readily when eaten.

Shortening for baked products must contain solid fractions of proper crystalline type to aid in the incorporation of air into the batter or dough during mixing. The light foam structure is then fixed by gelation of starch in the flour when baked.

Table II
Functional characteristics of fats/oils in food products*

LUBRICITY**

FRIED FOODS AND SNACKS SALAD DRESSING/ MAYONNAISE, SALAD AND COOKING OILS, FILLED FOOD PRODUCTS, ETC.

LUBRICITY/STRUCTURE
MARGARINES AND VANASPATI, AND SHORTENINGS FOR BREAD, ROLLS, ETC.

LUBRICITY/AERATION
SHORTENINGS FOR CAKES, COOKIES, BISCUITS, ETC.

LUBRICITY/STRUCTURE/AERATION
WHIPPED TOPPINGS, CREAM ICINGS, BAKERY FILLINGS, ICE CREAM, ETC.

LUBRICITY/STRUCTURE/MOISTURE BARRIER
DANISH AND PUFF PASTRY, CONFECTIONERY COATINGS, ETC.

Cochran (1995)

*IMPOSED VARIABLES ARE FLAVOR AND FLAVOR STABILITY.
**FOR FRIED FOODS THE FAT/OIL ALSO SERVES AS A HEAT EXCHANGE MEDIA

Whipped products such as toppings and icings require crystalline fat solids to aid the incorporation of air to make a light fluffy mix with water, sugar and other ingredients and to produce a fat matrix which will stabilize and support the icing and keep it from losing air, slumping or leaking.

Danish or puff pastry require solid fat structure to form fat layers of separate layers of dough. These fat layers in turn provide a barrier to the steam generated in baking causing the "puff" or "spring" during the baking, also they inhibit moisture penetration to preserve the crispners of the flakes.

Confectionery coatings require fat to give a hard brittle structure which can be molded and handled without deforming and which will prevent moisture migration from fillings. Because of the high level of fat in the coating, it must melt readily to avoid a waxy mouthfeel.

All fat and oil systems are mixtures of mixed triglycerides. These fat systems whether naturally occurring or produced as a result of hydrogenation, are made up of many entities having individual characteristics, such as different melting points. These individual entities if they were isolated would be either a liquid or solid. In a given system, many of the normal solid entities are in solution, that is, liquid, depending on ambient temperature. The functional properties of the system are directly related to the type of triglycerides present. The higher melting ones provide structure and the lower melting ones provide lubricity. All solid triglycerides are not equivalent in function since they may differ in crystallization properties as well as melting point. The liquid portion always behaves as a solvent for the higher melting entities.

The principal concerns in formulating fat systems for functionality are the solid-liquid ratio at various temperatures and the crystalline tendencies of the solid fraction.

Table III
Compositional-functional relationships*

	MELTING POINT °C		
GROUP I	72		
GS3	68	STRUCTURE @ 22°C/37°C	MOISTURE BARRIER
	63		
	56		
GROUP II	42		
GS2U	38	STRUCTURE @ 22°C	
	35		
	32	LUBRICITY @ 37°C	AERATION
	30		
	27		
GROUP III	23		
GSU2	16		
	8		
	6		
	1		
		LUBRICITY	
GROUP IV	-1		
GU3	-3		
	-6		
	-7		
	-14		

*IMPOSED VARIABLE IS CRYSTAL/CRYSTALLIZATION HABIT

Cochran (1975)

For formulation purposes the solid-liquid ratio is measured by an empirical test called the Solid Fat Index. This test measures the dilation of a sample placed at various temperatures and the SFI is calculated based on the difference in density of the solid and liquid. Measurements are usually taken at 10°, 21.1°, 26.7°, 33.3° and 40°C so they cover the range from below ambient temperature to above body temperature. The SFI may also be determined by Nuclear Magnetic Resonance which is very convenient but requires much more expensive equipment.

The solid-liquid ratio may be controlled by blending liquid oils with solid fats such as palm oil or beef tallow or with solid fats made by hydrogenation of liquid oils by special techniques. In formulation of products from soy oil, it is a common practice to hydrogenate a number of base stocks by different techniques and to different end points and blend these base stocks in different proportions to obtain the desired SFI.

The SFI correlates with the physical hardness of the plasticized fat. Hardness is important in the use of a fat in food preparation since it determines how the fat will cream and mix with other ingredients. The SFI also determines the structural contribution to the finished food.

The SFI of the shortening at the temperature of use is critical. If the SFI is too low, it will be excessively soft and blend in to readily; if the SFI is too high, it will be hard and difficult to mix. In either case the aerating function will be impaired. Shortenings which have a small variation in SFI over a wide temperature range are said to have a wide plastic range. Wide plastic range is desirable in shortenings which may be used under a variety of temperature conditions and where aeration and high temperature structure are important. Plastic range is less important in shortenings which are used under controlled conditions or in the melted state as in frying.

In some fat systems it is desirable to have high solids to give structure to a high fat food, such as margarine or chocolate at ambient temperatures and low solids at high temperatures so that it melts readily in the mouth. Such products are formulated to have a steep SFI curve or short plastic range.

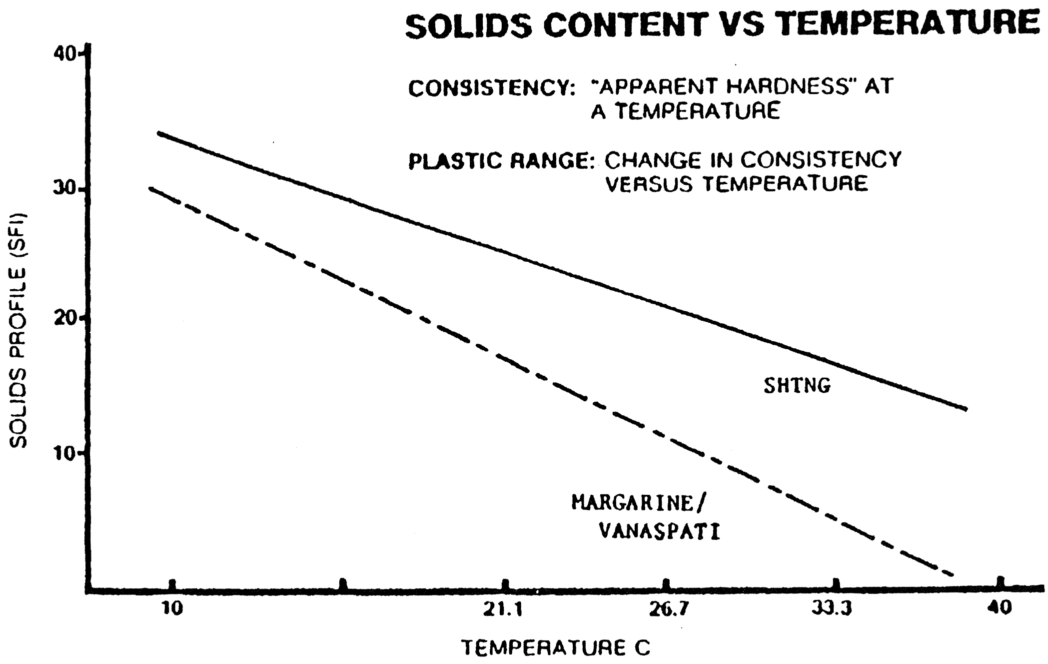

Figure 1

In addition to the solid-liquid ratio the crystal tendencies of the solid portion is important in formulation. Two crystal forms are recognized - beta and beta prime. Beta prime is a fine needlelike Crystal which forms a solid fat matrix which entraps the liquid portion and produces a smooth plastic structure when the shortening is chilled and tempered. Beta-prime shortenings also have the ability to entrap air when mixed or creamed with sugar and other ingredients to make light well aerated cake and icings. The beta crystal form is higher melting and more compact than the beta-prime form. In micrographs the crystals appear as discrete globular particles. These are not effective in entrapping the liquid portions of the fat and the resulting structure is lose and poorly defined. After chilling and tempering the texture may be brittle, rubbery, mushy or grainy rather than smooth and plastic.

All fat systems form Beta-prime crystals when chilled rapidly in the scraped wall heat exchanges used for shortening and margarine. Some formulations will remain stable in the Beta-prime configuration while others will transform to the Beta form. This transformation is accelerated by temperature changes while cause the solution and dissolution of the solid fraction in the liquid fraction.

For the most products the Beta-prime form is desired because of its stable physical characteristics and desirable mixing and aeration properties. For some shortenings used in the melted state the Beta forming tendency is acceptable. For a few products such as lard for pies the Beta form is desirable.

The crystallation tendencies are an inherent property of the source oil or fat from which the solid fat is derived. This table shows the crystal tendencies of the more commonly used edible fats and oils (Table IV). You will note from this that soy oil has beta crystal tendencies. Soy oil when hydrogenated completly (i.e., to less than 10 Iodine Value) produces a hard fat which is a strong Beta former. Such hard fat is not suitable in most types of shortening or margarine where the Beta prime crystal is desirable. Therefore, for bakery shortening which require a portion of very hard fat for structure, the hard fat is made by hydrogenating palm oil, cottonseed oil or beef tallow.

Table IV
Classification of fats and oils according to crystal habit

BETA-TYPE	BETA PRIME-TYPE
SOYBEAN	COTTONSEED
SAFFLOWER	PALM
SUNFLOWER	TALLOW
SESAME	HERRING
PEANUT	MENHADEN
CORN	WHALE
LEAR	HEAR
OLIVE	
COCONUT	MILK FAT
PALM KERNEL	
LARD	MODIFIED LARD
COCOA BUTTER	

Wiedermann (1968.1978)

When soy oil is partially hydrogenated, (i.e., in the range 60 to 90 Iodine value) and these stocks are judiciously blended margarine and shortenings which are stable in the beta-prime crystal form can be produced. The major quantity of margarine produced in the U.S. is made entirely from soy oil by this technique.

2. HYDROGENATION

The characteristics of partially hydrogenated soy oil are controlled by conditions of hydrogenation. Factors involved are: temperature, pressure, agitation, catalyst type and activity and catalyst concentration. Agitation in hydrogenators is dependent on design and not a variable under operator control. Increasing hydrogenation temperature and/or decreasing hydrogenation pressure increases the selectivity of the reaction, e.g., promotes more rapid hydrogenation of linoleate over oleate and also increases the rate of *trans* acids formations. From a practical standpoint in formulation selective conditions, e.g., high temperature low pressure increase the slope of the SFI curve while non-selective conditions e.g. lower temperature, high pressure decrease the slope of the SFI curve. This is shown graphically in figure 2.

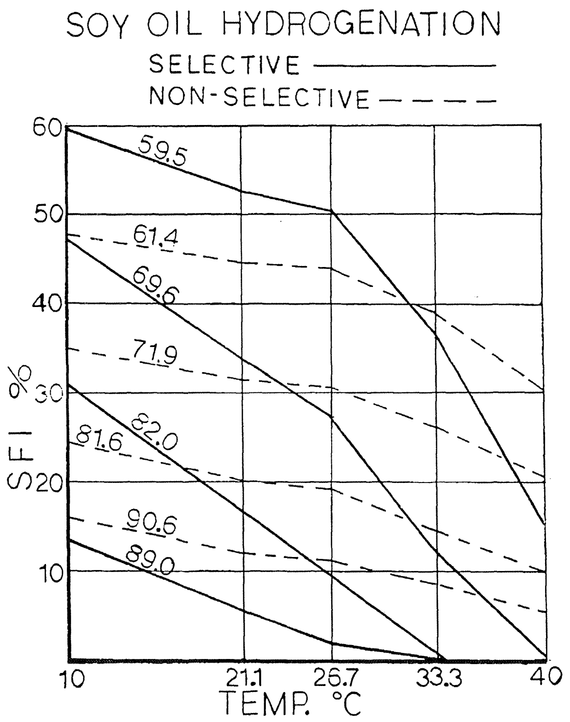

Figure 2

The solid lines represent selective conditions (485°F or 252°C and 10 psig.) the dashed lines represent non-selective conditions (260°F or 127°C and 40 psig). The numbers on the curves are iodine values so each pair of curves represent products hydrogenated to approximately the same Iodine Value. You will note that the SFI curve for selective hydrogenation is much steeper than for non-selective. For example compare the curves at about the 70 I.V. level. The selective stock is more than 10 points higher than non-selective (47 vs. 36) at 10°C, but at 40°C the selective stock has almost no solids while the non selective has about 21.

In general the non-selective stocks are used in formulation of shortenings which will be mixed with other ingredients and require good creaming characteristics. The flat SFI produces wide plastic range shortenings that are plastic and mixable over a wide temperature range.

The selective stocks are preferred for products such as margarine which should remain firm at ambient temperatures but melt in the mouth.

Stocks may be hydrogenated with varying degrees of selectivity and different stocks combined by blending to give a great variety of physical characteristics.

In addition to modifying the physical properties of oils, hydrogenation is also important in increasing the resistance of oils to oxidations and to improving shelf life and resistance to breakdown in frying. Generally, the greater the degree of unsaturation the more susceptible the oil is to oxidation reactions which take place at the double bonds. Selectively hydrogenated fats are more stable to oxidation than non-selectively hydrogenated fats with the same degree of hydrogenation. This is because selective hydrogenation reduces the polyunsaturates to a greater degree. In frying fats and in fats for foods such as biscuits and crackers where long shelf life is desired the bases which are selectively hydrogenated or which have been hydrogenated to a greater degree may be preferred, even at the sacrifice of other functional properties.

At this point the question may well be asked - How does one arrive at processing conditions to produce specific products? The answer is by testing and experience. Once the desired conditions are established, they must be followed carefully on each subsequent batch and the integrity of the product is verified by control testing after each step.

The next three slides illustrate how products are formulated using a base stock program. The first (table V) shows a series of 5 base stocks and the conditions of hydrogenations. Stocks No. 1 and No. 2 are non-selectively hydrogenated, have rather flat SFI curves and would be used primarily for shortening stocks No. 3 and 4 are more selective and are more suitable for margarines. Stock No. 5 is a lightly hydrogenated stock with very low SFI.

Table VI shows four shortening formulas made from these bases. The hard fat used may be either fully hydrogenated palm oil or cottonseed oil. The first formula is for an all purpose shortening such as would be used by a commercial baker. It is important that this have a wide plastic range and good creaming and aeration properties. The use of a soft base stock plus a relatively high percentage of hard fat with beta prime crystal tendencies provides these. Since fresh bakery products such as cakes and icings do not require long shelf life, the lower AOM stability is acceptable. Since the fat is combined with other ingredients high solids at body temperature is not objectionable.

In the frying fat formulation plastic range and mixing characteristics are unimportant since the product is used melted in frying. Low solids at body temperature are desirable since large quantities of the fat are absorbed on the surface of the fried good and impart a greasy or waxy taste sensation if the fat does not melt readily. Resistance to oxidation and polymerization caused by the high temperatures in the frying kettle is desirable. These criteria are satisfied by a base stock hydrogenated to a low iodine value with a minimum of hard fat added.

Speciality fat No. 1 is a fat used for the filling of sandwich cookies. This filling is a mixture of 1/3 fat 2/3 powdered sugar. High solids in the ambient temperature range are desirable so that the filling will set up and not squeeze out from between the base cakes. Since this is a high fat product, there must be low solids at body temperature.

Table VII shows three margarine oil formulas. The first is a very popular formula in the U.S. Since it utilizes unhydrogenated soy oil at a high level, it retains a high level of polyunsaturates which is desirable nutritionally.

Table V
Hydrogenation conditions soy oil base stocks

BASE STOCK N°.		1	2	3	4	5
HYDROGENATION CONDITIONS:						
TEMPERATURE °C.		165	165	218	218	177
PRESSURE psig		15	15	5	10	15
CATALYST - % NI		0.02	0.02	0.05	0.02	0.02
FINAL I.V.		83-86	70-72	64-68	73-76	106-108
SOLID FAT INDEX	@ 10°C	16-18	40-43	58-61	36-38	4 Max.
	@ 21.1°C	7-9	27-29	42-46	19-21	2 Max.
	@ 33.3°C	—	9-11	21 Max.	2 Max.	—

Table VI
Shortening formulation

SHORTENING TYPE	FORMULA	AOM HOURS	SOLID FAT INDEX 10°C	21.1°C	33.3°C	40°C
ALL PURPOSE	88% N°. 1 12% HARD FAT*	40+	22-24	18-20	13-15	10-12
FRYING	97% Nº. 2 3% HARD FAT*	100+	41-44	28-30	12-14	2-5
SPECIALTY Nº. 1	35+5% N°. 3 64+5% Nº. 4 1% HARD FAT*	100+	45-48	31-34	10.5-12.5	1.5 Max.
SPECIALTY Nº. 2	30+5% N°. 3 70+5% N°. 4	100+	43-47	27-30	6-9	1.5 Max.

*Hard fat is fully hydrogenated palm or cottonseed oil

Table VII
Margarine formulation

FORMULA	SOLID FAT INDEX 10°C	21.1°C	33.3°C
50% Nº. 3 50% SOY OIL	20-26	13-17	1.5-3
38% Nº. 3 20% Nº. 4 42% Nº. 5	30 Max	17.5 min	3.5 Max
50% Nº. 1 25% Nº. 3 25% Nº. 4	28-30.5	16-18	2-3

The other formulas are a combination of three different hydrogenated base stocks.

These are only a few examples of soy shortening and margarine oil formulas. They are presented to illustrate the procedures for formulating soy oil products using hydrogenated base stocks. In the U. S. a refiner may make a large number of formulas for different purposes and different customers. Large food processors will often have individual specifications for products specifically adapted to their end product and process. It is probable that in Nigeria that preferred products would not identical to those in the U.S. and would be adapted to local food products and tastes.

In addition to products which are made from predominantly soybean oil, soy oil can be used advantageously in blending with other fats. For example, good quality all purpose shortening can be made from a formula consisting of

64 ± 5% Palm Oil or Tallow
21 ± 5% Soy Oil
9 ± 2% Palm Oil or Tallow Hard Fat

The variation in percentages of the ingredients is necessary to compensate for natural variation in hardness of the palm or tallow. The only hydrogenated fat in this formula is the hard fat. If double pressed palm oil stearine is available, it can be used in as the hard fat fraction in a modification of this formula. The control SFI for this formula would be:

@ 10°	26-30
21.1°	20-24
26.7°	19-23
33.3°	17-21
40°	10-14

At this point I'd like to review some of the various types of margarine and shortening that are manufactured. First let's look at margarine.

3. MARGARINE

Margarine is defined in the WHO/Codex standards as containing 80% fat. Product containing less than this minimum must be labelled as imitation or by some other term such as "spread." These products may contain as little as 40% fat. In the U. S. the most popular imitation margarine is a 52% fat spread which claims about 30% of the market. The reduced fat products are less applicable to baking and frying than standard margarine and are consumed primarily as a spread.

Basically margarine consists of a water-in-oil emulsion. The aqueous phase may contain water, milk, milk products or a variety of other forms of edible protein including whey, casein, caseinate, vegetable proteins or soy protein isolate. In the U. S. is mandatory to include vitamin A at a minimum level of 15000 international units per pound. Optional ingredients include vitamin D, salt, potassium chloride, carbohydrate sweeteners, emulsifiers, preservatives, color additives, acidulents and alkalizers.

Margarine oil is the most significant ingredient both functionally and nutritionally. Physical properties of margarine oil are of primary concern since they determine the ability to print and wrap portions at high speed, spreadability at refrigerator and ambient temperatures and melt in mouth or taste sensation when eaten.

In recent years there has been increasing emphasis on higher levels of polyunsaturated oils in the diet. This has been reflected in the modification of margarine oil formulas to include high levels of liquid oils. Most of the stick margarine in the U. S. now contains 50% or more liquid oil, and soft or tub type margarine contain 80% or more.

The desired SFI pattern of stick margarine is an SFI below 28 at 10°C so the margarine will be spreadable at refrigerator temperature, above 14 at 21.1°C so the product will print well at high speed and hold its form at room temperature, and below 4 at 92° so that it melts readily in the mouth. Margarine for use in hot climates and where refrigeration is not available may require considerably higher solids at ambient temperatures.

Tub type margarine can have considerably lower SFI since the ridgid tub supports the product from fill to service at the table. SFI of approximately 10 at 10°C and 5 to 6 at 21.1°C is typical.

Deodorization to produce a perfectly bland flavor is more critical with margarine than with any other type of oil, since margarine is widely consumed as a table spread.

In addition to table spread special margarines are made for the use of bakers and food processors. Although these are emulsion type products of the margarine oils are basically the same as the properties of shortenings formulated for the same purposes.

4. SHORTENINGS

Many types of shortening are manufactured for use in the home, by food service establishments, and by food processors.

For home use in the U.S. a general purpose shortening suitable for a great variety of uses such as baking cakes, pies, cookies, deep fat frying, pan frying and greasy pans. This is commonly formulated from about 90% non-selectively hydrogenated soy oil and 10% of palm or cottonseed hard fat. To improve cake baking performance — make cakes lighter and more moist — a small amount of emulsifier is added. This is commonly a mono and diglyceride added at a level to give about 1.5% monoglyceride. The monoglyceride tends to lower the smoke point, but the effect is not sufficient to materially affect the use of this shortening in frying. Emphasis is on a smooth plastic product which is easily spooned and mixed.

5. COMMERCIAL SHORTENINGS

A great variety of commercial shortenings are produced. Many of these are highly specialized and may be formulated for one specific type of product. Larger food processors and food service organizations will frequently have their own individual specifications for the products which they purchase. These specifications will be designed to provide optimum performance in their particular product and process.

I'd like to at this time describe a number of the more common types of shortening.

All purpose shortening is designed for general use by bakers and food service. Emphasis in this shortening is to provide excellent mixing wide plastic range and good aerating properties together with a moderate oxidative stability. Earlier in this paper we showed a specific formulation for a typical all-purpose shortening.

This same formulation is used as a base for more specialized products.

Cake and icing shortening are made by combining edible emulsifiers with the all-purpose base. Most commoly the emulsifier is a mono and diglyceride used a level of approximately 2.5 to 3.0% monoglyceride by analysis. The monoglyceride is made from soy oil hydrogenated to approximately 80 I.V. This formulation is not the optimum emulsifier for either cake or icing, but is a compromise which makes the product suitable for both uses. Cake performance can be improved by increasing the level of emulsifier or by increasing the saturation of the monoglyceride. Icing performance can be improved by decreasing the level of monoglyceride or decreasing the saturation of the monoglyceride.

The use of emulsifier in cake shortening enables the baker to increase the amount of sugar and liquids (water, milk, eggs, etc.) and to incorporate more air into the batter. The result is a sweeter, more moist, lighter and finer textured cake. In icings more moisture, sugar and air can be incorporated to give greater sweetness, lightness and smoothness.

While the dual-purpose cake and icing shortening satisfies many bakers needs, there are even more specialized shortenings for icings or for cakes. These shortenings incorporate more sophisticated emulsifier systems but use the same type of shortening base.

Icing shortenings which give the greatest air and moisture incorporation use relatively low levels of more hydrophilic emulsifiers. Two systems are preferred (1) polyglycerol esters and (2) polysorbate 60 in combination with monoglycerides. The base fat plays an important role in the function of these shortenings, since the very high level of aeration requires maximum structural support so the icing will not separate or soften.

Specialized cake shortenings are used in large quantities by the cake mix industry and by large wholesale bakers. These products are based upon the use of emulsifier systems which enhance the aerating properties of the shortening and reduce the importance of the crystalline structure of the fat. Emulsifier systems include propylene glycol esters with mono and diglycerides. Polysorbate 60 and sorbitan monostearates with mono and diglycerides, acetylated monoglycerides and lactylated monoglycerides. All of these systems have two common characteristics — they are based on saturated fatty acids and are mixtures of several different chemical entities. Levels of emulsifier may be comparatively high, comprising as much as 25% of the total fat system.

Since the aerating function is performed by the emulsifier rather than depending on the crystalline structure of the base fat, there is considerable freedom in formulation. Some products contain a large portion of unhydrogenated soybean oil which provides a high degree of lubrication and a desirable moist and tender crumb.

6. FRYING SHORTENINGS

High stability frying shortenings have assumed increasing importance with the growth of the fast food industry. Emphasis in these shortenings is on maximum resistance to break down in the frying kettle. In production of these shortenings hydrogenation is designed to eliminate the polyunsaturated materials. Since these shortenings were melted for use plasticity is of less importance. Hydrogenation may be carried to the point where the product is fairly hard at room temperature.

Because deep fat frying shortenings are present on the surface of foods, high solids at body temperature can cause a greasy or waxy taste. Selective hydrogenation is preferred since it permits hydrogenation to a relatively low I.V. and still retaining a low SFI at higher temperatures.

7. FLUID SHORTENINGS

While shortenings have customarily been plastic or semi-solid, a few years ago fluid shortenings were introduced. These consist of a liquid oil which may be unhydrogenated or lightly hydrogenated soybean oil in which hard fats and/or hard emulsifiers are incorporated as finely divided crystals which remain in suspension. The desired crystal is the Beta configuration, since it is the highest melting and most stable. Therefore, the preferred hard fat is fully hydrogenated soy (less than 5 I.V.). Emulsifiers are chosen which have Beta crystal tendencies.

The most important of these products is fluid shortening for frying. This is widely used in restaurants because it has the convenience of being pourable and is more stable than liquid vegetable oils. This shortening is made by hydrogenating soy oil to 102 to 110 I.V. and blending with 2 to 8 percent of soy hard fat. Special cooling techniques are required to develop the very fine crystals which will remain in suspension.

Antioxidants and methylsilicone an antifoaming agent are added to this product to improve resistance to breakdown in the frying kettle.

A variation of this product is a griddle grease for restaurant use which is artificially colored yellow and flavored with butterlike flavor.

Fluid shortenings based on the same principles of formulation and containing emulsifiers have been developed for use in commercial cake and bread baking.