separate congeal point data that gave the penetrations he required for lards, tallows and blends of meat and vegetable fats. His consistency control record was outstanding.

The reason this system worked was that there is a definite relationship between the 92 F solids and congeal point. Since the slopes of the individual meat fat curves remain the same (in the range of shortening consistencies), determination of the congeal point effectively determined the entire SFI curve.

In summary, from refining through hydrogenation, meat fats are easier to process than vegetable oils. While their degree of saturation may limit their usage, this same quality also makes the processing easier than for vegetable oils.

Meat Fat Formulation

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ABSTRACT

Edible usage of meat fats has somewhat declined over the past years. This can be attributed to several factors. First, the advancement of hydrogenation technology has led to the development of highly functional vegetable oil products. Second, there has been an increased emphasis on Kosher products. Third, various questions relating cholesterol to risks of heart disease have generated some marketing concerns over meat fat usage.

Meat fats are still a factor in the edible oils market. U.S. consumption of meat fats in 1976 was 4.1 billion pounds, approximately one billion pounds for edible usage. Because of their triglyceride profiles, they are excellent sources of highly functional products for bakery applications. They have tended to be the "Cadillac" around which hydrogenated vegetable oil products have been developed. In addition, the economics of these products have generated significant savings for end users. Flavor attributes of meat fats have, in other cases, been the reason for their sole usage in certain specific products.

In shortening formulation, meat fats are merely one of many triglyceride sources. They can be blended with any vegetable oil source. They can be subjected to the same processing as other oils in order to modify physical chemical properties such as SFI, melting point, consistency and oxidative stability.

This paper will discuss specific applications where lard and tallow contribute unique functionality. It will then discuss various modifications which can be employed to insure more consistent performance or to customize products to specific applications.

DISCUSSION

Table I compares typical fatty acid compositions of lard and tallow with several common vegetable oil sources. As noted, both products contain substantially high levels of saturated fatty acids and are solid at room temperature. Vegetable oils, excepting palm oil, are high in unsaturated fatty acids and are liquid in nature. Coconut and palm kernel, being "high lauric acid," are solid at room temperature; however, they tend to crystallize into a brittle non-plastic consistency. The solid triglycerides in lard and tallow provide plasticity, which is ideal for functionality in bakery systems. The vegetable oils, soybean and cottonseed, etc., must be hydrogenated to the same degree of saturation to achieve functionality. Formulation must adjust for inherent variations of composition in the animal fats.

LARD

Table II shows typical analytical composition ranges of crude lard. Variations are in iodine number and in the total fatty acid content. These variations are a result of factors relating to diet, climate and the overall structure of the animal. Even with this variation, lard contains a high percentage of medium melting disaturated monounsaturated (GS2U) triglycerides. These triglycerides tend to be largely in a symmetrical arrangement. Hence, the fat crystallizes in the beta form. Uses for lard, therefore, center around applications requiring low structure and high lubricity. The main application is in pie crusts.

TABLE I

Typical Fatty Acid Composition—Common Oil Sources

Fatty acid	Soybean	Cottonseed	Palm	Lard	Tallow	Coconut
Lauric	0.1	0.1	0.1	0.1	0.1	46.5
Myristic	0.1	0.7	1.0	1.4	2.8	19.2
Palmitic	10.2	20.1	42.8	23.6	23.3	9.8
Stearic	3.7	2.6	4.5	14.2	19.4	3.0
Oleic	22.8	19.2	40.5	44.2	42.4	6.9
Linoleic	53.7	55.2	10.1	10.7	2.9	2.2
Linolenic	8.6	0.6	0.2	0.4	0.9	0.0

TABLE II

Variations in Crude Lard[a]

Lard analytical composition	
Iodine number	46 - 70
Saponification number	195 - 202
Titer, C	36 - 42
Wiley melting point, C	46 - 48
Fatty acid composition %	
Myristic	1 - 4
Palmitic	20 - 28
Stearic	5 - 14
Oleic	41 - 51
Linoleic	2 - 15
Linolenic	Tr - 0.1
Arachidonic	0.3- 1.0
Glyceride composition	
Total GS_3	2 - 5
Total GS_2U	25 - 35
Total GSU_2	50 - 60
Total GU_3	10 - 30

[a]Swern et al., *Bailey's Industrial Fats and Oils,* 3rd edition, p. 189.

TABLE III

Functional Characteristics of Pie Shortenings

- Plasticity at refrigerated temperatures
- Loosely bound oil fraction - lubricity
- High solids - flaky texture
- Rapidly melting, rapidly dissolving solids - mouth feel

Table III notes functionality requirements of pie crust shortening. In mixing a pie crust, the shortening is rather loosely mixed into the dough. Overmixing causes the shortening to be absorbed into the dough, creating a tougher pie crust and excessive shrinkage. To control the absorption, mixing is conducted at colder dough temperatures. For adequate rolling and forming, the shortening must have plasticity at refrigerated temperatures. In addition, the solids content of the fat should be sufficient to provide flakiness.

Lard has the SFI profile required for flakiness and, due to its beta crystalline habit, also provides the desired low temperature plasticity. Adjustment must be made to assure constant consistency despite variations in the source of crude. Controls of consistency are accomplished through controls of both formulation and the votation/tempering conditions.

Most formulations are developed around the addition of 2-3% fully hydrogenated lard hard fat. The level of hard fat can be raised or lowered in deference to the consistency of the crude received. This, however, modifies the slope of the SFI profile. If usage requires a critical control of SFI, other options must be used. Figure 1 demonstrates effects of partially hydrogenated lard addition. As noted, the solids increase is additive. Consequently, a gradual increase across the entire profile is obtained and the slope is essentially unchanged. Fully hydrogenated hard fat addition is additive at the higher temperatures, but has little effect at lower temperatures. Consequently, the entire slope is flattened.

Control of consistency is also achieved through a control of the votation and tempering conditions. Effects of tempering are quite dramatic (Table IV). Storage at 70-80 F for 48 hr develops a plastic, rubbery consistency. Conversely, if the shortening is subjected to immediate refrigeration after votation, the consistency is loose structured and brittle. Dependent upon the user, either condition may be desirable, but normally not interchangeable.

Lard also is used extensively in deep fat frying and, to a lesser degree, in emulsified cake shortening.

In deep fat frying, lard is said to contribute specific meat-like flavors to the fried food. It is generally quite stable under the abusive conditions used. Where there is not a specific flavor requirement, it may be used by itself or blended with tallow and/or vegetable oil for economic reasons.

A significant amount of lard may be used in highly emulsified cake shortening, particularly propylene glycol monoester type systems. The emulsifier levels must be adjusted to counteract structural effects compromised by switching from a beta prime tending fat source to a beta tending source. Usage in these shortenings is dictated by the oil markets.

TALLOW

Table V lists common variations in the composition of crude tallow. Like lard, a considerable variation is noted in iodine value and the content of palmitic, stearic and oleic acids. Tallow contains an even higher level of monounsaturated disaturated GS2U triglycerides and is solid at room temperature. The geometric arrangement of these triglycerides is highly assymmetric and, therefore, tallow crystallizes in the beta prime form. Uses center around applications requiring combined lubricity and structure such as cakes and icings and Danish puff pastry.

Table VI lists the functional requirements of cake shortenings. Functionality is contingent upon the ability to emulsify the cake batter while concurrently affecting the degree of aeration required. Proper formulation and mixing results in cakes having the desired volume and grain symmetry.

The beta prime crystalline structure, as in tallow, provides a good matrix upon which air bubbles can be entrapped and retained. In emulsified cake shortenings, the emulsification system reduces, to a degree, structural requirements required of the shortening. The solids content and consistency provide ideal plasticity for rapid incorporation into the cake mix. Regardless of the system used, tallow is an excellent fat substrate in these systems.

Table VII notes functional requirements in shortenings used for icings. Shortening structure is a prime requirement. Icings contain two main structural components, sugar and shortening. More recent systems use increased amounts of

EFFECT OF PARTIALLY HYDROGENATED LARD

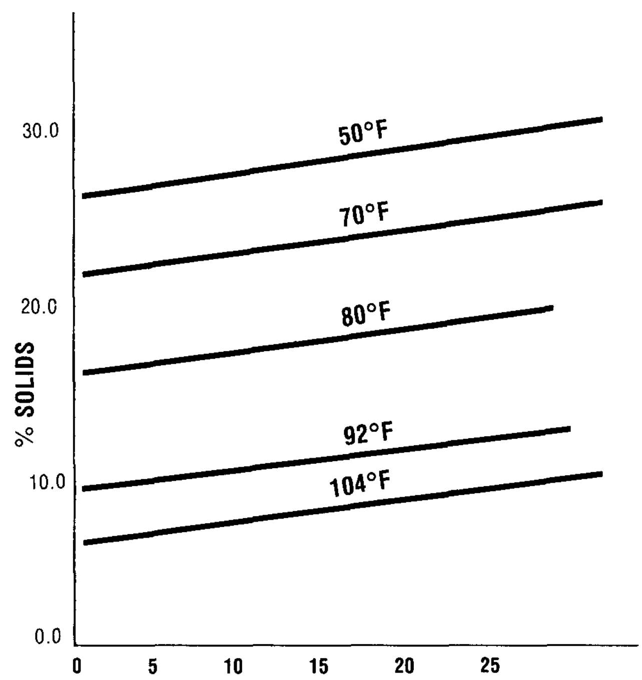

FIG. 1. Effect of partially hydrogenated lard.

TABLE IV

Effects of Tempering on Lard

Temperature (F)	Time (hrs)	Consistency
70 - 80	48	Rubbery, plastic
40	48	Brittle, loose structured, non-plasticity

TABLE V

Variations in Crude Tallow[a]

Tallow analytical composition	
Iodine number	35 - 48
Saponification number	193 - 202
Titer, C	40 - 46
Wiley melting point, C	47 - 50
Fatty acid composition %	
Myristic	2 - 8
Palmitic	24 - 37
Stearic	14 - 29
Oleic	40 - 50
Linoleic	1 - 5
Glyceride composition	
Total GS_3	15 - 28
Total GS_2U	46 - 52
Total GSU_2	20 - 37
Total GU_3	0 - 2

[a]Swern et al., *Bailey's Industrial Fats and Oils*, 3rd edition, p. 192.

corn syrup, either high fructose or regular. These formulations place an added load on the shortening. The beta prime crystalline structure of tallow is basic to providing this structural matrix. Adjustment in the level of tallow hard fat may be required to modify the spreading properties or provide increased stability against syneresis or air cell coalescence.

Emulsifiers are added dependent upon the degree of aeration required and the moisture level of the finished icing. Straight mono- and diglycerides are added to medium aeration systems. For more highly aerated systems, either a blend of monodiglycerides and polysorbate 60 or 80 or a polyglycol ester system is used.

The structural properties of tallow also are used advantageously in margarines for puff pastry and danish. These systems normally are A/V blends intended to provide specific compositions and SFI profiles to achieve the roll-in properties, flakiness and expansion desired. The general intent is to combine various fractions to achieve workability over the widest temperature range.

Tallow also is used extensively in deep fat frying. Over the last 10-15 years, a major fast food franchiser became the prime mover in utilizing caustic refined, undeodorized tallow as a deep fat frying shortening for french fries. The shortening is said to contribute a specific flavor to the fries and is the apparent reason for its marketing success. The extent of flavor effect may be debated among researchers. Many claim that operational factors within the franchises influence the flavor more than the specific fat used. Regardless of the outcome of these discussions, the fact remains that this marketing success has led to increased usage of caustic refined, undeodorized tallow among fast food franchisers.

Applications evaluating the potential usage of caustic refined tallow should consider the reduced oxidative stability of the shortening. Practical usage is contingent upon applications where rapid turnovers exist and in products which do not require excessively long shelf lives.

ANTIOXIDANTS IN MEAT FATS

Meat fats, like vegetable oils, are susceptible to oxidation at the double bonds and, hence, to rancidity. Antioxidants are added to improve stability.

Antioxidants tend to behave somewhat differently in meat fat and vegetable oil systems. Table VIII lists common AOM values we have obtained for various fat antioxidant systems.

Without antioxidants, excepting palm oil, all fats are low in AOM. The vegetable oils, despite their high levels of polyunsaturates, are equal to or superior to lard and tallow. This is most likely due to the absence of natural antioxidants, such as tocopherol, in meat fats.

BHA and BHA/BHT combinations are much more effective in lard and tallow than in vegetable oils. A five-fold increase is noted with te addition of 100 ppm BHA and a nine- 10-fold increase is obtained when 100 ppm each of BHA and BHT is added. In vegetable oils, no data was obtained for 100 ppm BHA. Results obtained from the BHA/BHT blend, however, suggest that, again excepting palm oil, BHA and BHT are relatively ineffective.

TBHQ addition is effective in each system. Again the degree of improvement is much greater in the meat fat systems and with palm oil. 100 ppm increases stability of lard and tallow by six to 10 times. 200 ppm increases the stability of vegetable oils by only three to five times.

USDA regulations limit the amount of antioxidant which can be added. BHA and BHT can be added up to 200 ppm total antioxidant. TBHQ can be added at a level of 100 ppm singly or in combination with BHA and/or BHT to a level of 200 ppm total antioxidant. Combination of TBHQ with propylgallate is not lawful.

TABLE VI

Functional Characteristics of Cake Shortenings

Lubricity and aeration
Cake shortening effects

Mixing stage
- Creaming ability
  - Function of:
    - Crystal form
    - Emulsifier composition
- Level of liquids/sugar tolerated

Finished cake quality
- Volume
- Grain/symmetry
- Moistness
- Storage life

TABLE VII

Functional Characteristics of Icing Shortenings

Lubricity, structure and aeration
Icing shortening effects

Body and texture
- Creaming ability
  - Beta prime form
  - Emulsifier composition
- Spreadability/stability
  - Shortening/sugar/stabilizer level
  - Emulsifier

Mouth feel
- Shortening composition
- Liquid level
- Granulation of ingredients

An overall lubricity effect achieved from icing and cake combined.

TABLE VIII

Antioxidant Effects on Active Oxygen Method (in hours)

	Antioxidant (level)				
Type of oil	None	BHA (100 ppm)	BHA/BHT (100 ppm each)	TBHQ (100 ppm)	TBHQ (200 ppm)
Lard	4	20	58	46	73
Tallow	16	95	138	104	133
Soybean	12	–	12	37	45
Palm	48	–	85	165	235
Peanut	25	–	22	50	75
Corn	14	–	16	32	51
Cottonseed (winterized)	10	–	12	39	43

LARD/TALLOW BLENDS

When lard and tallow are blended, unusual effects are obtained. Both crystal inhibition and crystal promotion effects are noted. Figure 2 demonstrates the effects of blends up to 63% lard/37% tallow. At 50 F, lard containing 27% solids and tallow having 28% solids results in a net increase of 6-8% solids when blended. The opposite effect is, however, noted at 80 F. Although tallow solids are 5% greater than lard, the solids of blends are depressed. Additive effects are noted at the other three temperatures, there

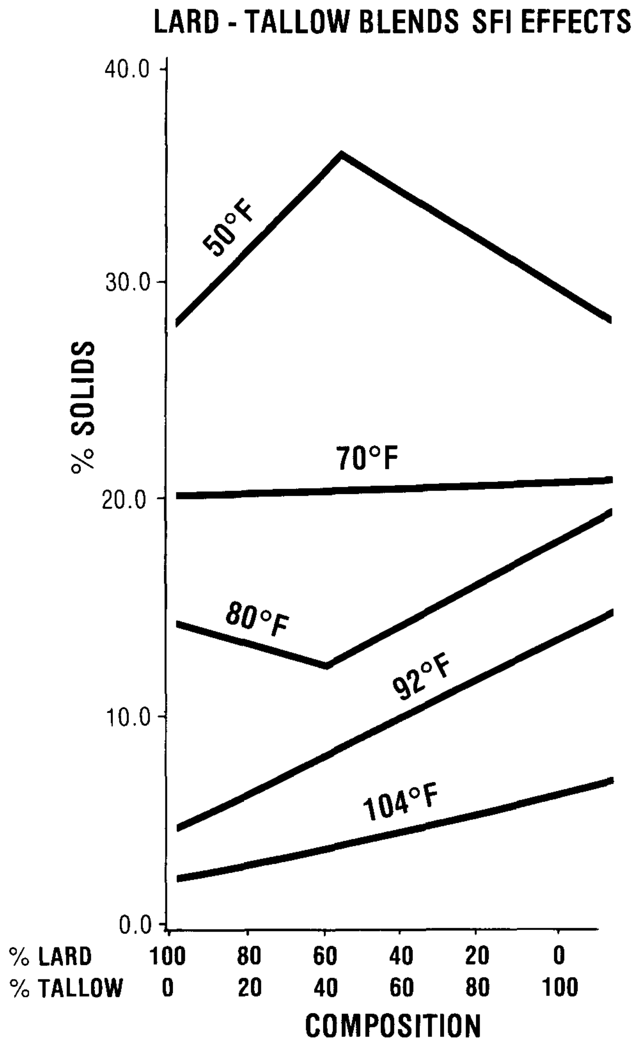

FIG. 2. Lard/tallow blends, SFI effects.

being no net change at 70 F and linear increases at 92 F and 104 F.

These effects are particularly important in the development of economic flex formulas. For optimum economics, one should critically measure the importance of solids at each temperature. If 50 F solids are basic to performance, definite restrictions are placed on the degree of blending which is allowed. If a depression of solids at 80 F is undesirable, there are again limitations on the degree of blending which is allowed. Specifications for these products should be based on SFI's obtained from the entire blend.

In this paper we have discussed the various aspects involved in formulating shortening products from meat fats. We have discussed the analytical composition of lard and tallow and how that chemistry relates to specific applications where they are used. We have further discussed factors relating to the oxidative stability of meat fats. Finally, we have discussed the unexpected effects on solids content obtained when lard and tallow are blended.

We have noted that lard and tallow, in some instances, are the best performing shortening source due to certain uniqueness relating to their triglyceride composition. Flavor considerations also have been a factor in usage. In other applications, they are one of a number of triglyceride sources that may be used to obtain the desired effect. In these cases, economics of the edible fats and oils markets determine the frequency of their usage.