

# Development of Edible Tallow Fractions for Specialty Fat Uses<sup>1</sup>

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## ABSTRACT

Edible beef tallow was effectively fractionated by an acetone crystallization procedure to yield five fractions: two solid glyceride fractions comprising 14% (ca. 7% each) of the original tallow; two liquid fractions of 59% and 7%; and one semisolid fraction of 20%. The solid glycerides were composed of ca. 80% saturates (saturated fatty acid glyceride components), approximately an equal mixture of palmitate and stearate, with oleate as the principal unsaturate. The liquid glycerides were composed of more than 65% unsaturates (unsaturated fatty acid glyceride components), predominantly oleate, with the saturates a 3:1 mixture of palmitate and stearate. The semisolid glyceride fraction was similar to cocoa butter. It was one-third unsaturated, mainly oleate with the saturates a mixture of palmitate and stearate. The thermal behavior of the fractions was studied by differential scanning calorimetry. The liquid fraction had a differential scanning calorimetry final melting profile similar to commercial salad oil and the profile of the semisolid fraction resembled that of cocoa butter. The semisolid fraction appeared to be compatible with cocoa butter over a wide range. Mixtures of 5 and 50% cocoa butter with the semisolid fraction had melting profiles similar to that of the original cocoa butter.

## INTRODUCTION

The 1970-71 domestic production of inedible tallow exceeded 5 billion pounds, and it is anticipated that the consistent yearly increase in beef production and consumption together with the trend in the industry toward centralized packaging of meat will lead to the production of 7 billion pounds by 1980 (1). This represents a major domestic investment in fatty raw material, of which a considerable portion is or could be of food grade quality.

While the use of edible tallow has remained constant at ca. 500 million pounds for several years, there is little doubt that the production of edible tallow would increase substantially if a more profitable market for the product

could be anticipated.

Studies from this laboratory (2) have previously contributed to expanded use of tallow in shortenings, but it is obvious that present demands are not sufficient to produce any great expansion of the edible tallow market. An earlier investigation (3) of glyceride composition had shown tallow to contain glycerides of widely different physical properties. In the present study, a fractionation scheme has been developed using acetone as solvent to separate edible tallow into liquid, solid and semisolid glyceride components. Thus the potential products and uses that can be made from tallow by blending and processing these fractions appears to be vast. A similar procedure could be applied to inedible tallow for the development of commercial products with special physical properties.

## EXPERIMENTAL PROCEDURES

The tallows used in this study were high quality, freshly rendered edible tallows obtained locally from two large commercial processors of beef. To obtain representative samples for the study, a 50 lb drum of tallow was melted, mixed thoroughly, transferred to 1 lb glass containers and stored at 2 C until needed.

### Crystallization

The acetone used in the study was anhydrous, reagent grade of low residue (0.0005%) distilled in glass. The outline of the crystallization scheme, solvent-sample ratios and the crystallization temperatures are given in Figure 1. Constant temperature rooms were used to obtain the crystallization temperatures of 25, 15 and 2 C. In each crystallization, the acetone solutions were held overnight (minimum of 16 hr) at the stated temperature with only occasional stirring during initial cooling. Solutions crystallized at 2 C were first cooled for 2 hr at 15 C. The solutions were filtered under mild vacuum at the crystallization temperatures using ordinary 14 in. diameter table-top Buchner funnels. The collected precipitates were washed on the funnels with 200 ml acetone previously cooled to the crystallization temperature. The fractions were freed of solvent by distillation at steam bath temperature under N<sub>2</sub>, followed by vacuum treatment on a rotary evaporator also under N<sub>2</sub> atmosphere. The isolated fractions were stored at 2 C and at all times treated under conditions designed to minimize oxidation.

### Analytical Methods

The tallow and tallow fractions were converted to methyl esters (4) and the fatty acid composition determined by gas liquid chromatography (GLC) employing an Aerograph 1522 gas chromatograph equipped with dual H<sub>2</sub> flame ionization detectors under conditions previously reported (5). The procedures for the pancreatic lipase hydrolysis of triglycerides, isolation of hydrolytic products and their conversion to methyl esters have been described (6). The glyceride composition of the tallow was calculated from the fatty acid composition and pancreatic lipase hydrolysis data according to the 1,3-random, 2-random fatty acid distribution theory proposed by Vander Wal (7). The glyceride composition of the tallow fractions in terms of saturated-unsaturated glyceride classes was estimated essentially by the procedure of Blank et al. (8) from silver ion thin layer chromatography (TLC), lipase hydrolysis and

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TABLE I

Fatty Acid Composition of Tallow (mol%)

Fatty acid	Triglyceride	2-Monoglyceride <sup>a</sup>
14:0	4.4	6.1
14:1	1.6	3.4
16:0	26.7	6.7
16:1	5.0	7.5
17:0	1.6	1.0
17:1	1.2	2.2
18:0	13.9	6.3
18:1	41.7	58.8
18:2	2.3	5.9
18:3	0.3	1.1
Others	1.3	1.0

<sup>a</sup>Lipase hydrolysis data.

TABLE II  
Principal Tallow Glycerides<sup>a</sup>, Calculated<sup>b</sup> (mol%)

Trisaturated		Disaturated		Monosaturated		Triunsaturated	
PPP	0.9	PPO	1.6	MOO	1.4	OOO	6.4
PPS	0.9	POP	7.9	POO	14.3	P'OO	1.5
PSP	0.8	PPP'	1.0	SOO	6.8	OP'O	0.8
PSS	0.8	PP'S	1.0	OMO	0.7	OLO	0.7
PMS	0.8	POM	1.5	OPO	0.7	Others	2.5
Others	3.5	PMO	1.5	OSO	0.7		
		POS	7.6	P'OP	1.6		
		PSO	1.5	P'OS	0.8		
		SPO	0.8	OLP	1.4		
		SMO	0.7	OLS	1.7		
		SOM	0.7	OP'P	1.8		
		SOS	1.8	OP'S	0.9		
		SSO	0.7	Others	8.0		
		PLP	0.8				
		SLP	0.8				
		PLS	0.8				
		Others	8.8				

<sup>a</sup>M = myristic; P = palmitic; P' = palmitoleic; S = stearic; O = oleic; L = linoleic.

<sup>b</sup>Vander Wal distribution (7).

#### GLC data.

Isolated *trans* acid content of the tallow and tallow fractions was determined by AOCS Tentative Method Cd 14-61 (9). Cloud points were determined according to AOCS Official Method Cd-6-25 (9). Cold test was evaluated by AOCS Official Method Cc-11-53 (9). Additional thermal data were obtained using a Perkin-Elmer DSC 1-B differential scanning calorimeter. Samples were placed in open aluminum pans and weighed on a Cahn Electrobalance Model RG. Weights of samples were ca. 10 mg in order to get melting profiles that could be recorded with an instrument attenuation of 16x. Heating rate was 10 C/min. Nitrogen flow measured at the bypass outlet was 13.3 ml/min. Naphthalene (99%) was used to calibrate the temperature axis. A sample stored at 15 C for a minimum of 48 hr was weighed as quickly as possible and placed in the sample holder of the instrument. An empty aluminum pan served as reference. The instrument was turned off prior to introduction of the sample in order to avoid any extraneous heating effect. A low temperature Dewar was put into place and the system was purged with N<sub>2</sub> for 5 min to remove traces of moisture prior to adding coolant (dry ice, ethanol). The system was allowed to cool to -15 C.

#### RESULTS AND DISCUSSION

The fatty acid composition of the tallow used in this study is shown in Table I. A sample from a second commercial processor had an identical composition. Although recent literature on the composition of commercial, North American, edible beef tallow is scant, the fatty acid composition of the tallow is similar to the mean values reported by Huston et al. (10) for samples taken from the perirenal and subcutaneous depots of 12 beef carcasses. The oleic acid content is slightly higher and the stearic acid content slightly lower than that reported by Barford et al. (11) for North American beef (ruffle) fat and that reported by Jurriens (12) for European beef fat. The composition falls within the specifications for edible beef tallow recommended to the Codex Committee on Fats and Oils by the AOCS (13). Also shown in Table I is the mole per cent of the fatty acids esterified in the 2 position of the glyceride, as determined from pancreatic lipase hydrolysis data.

The glyceride composition of the tallow, in terms of the 10 principal fatty acids was calculated by computer according to Vander Wal's distribution theory. The calculation was restricted to those glycerides present in excess of 0.001 mol%. This resulted in a total of 392 glycerides, of which 37 occurred in concentrations greater than 0.5 mol%

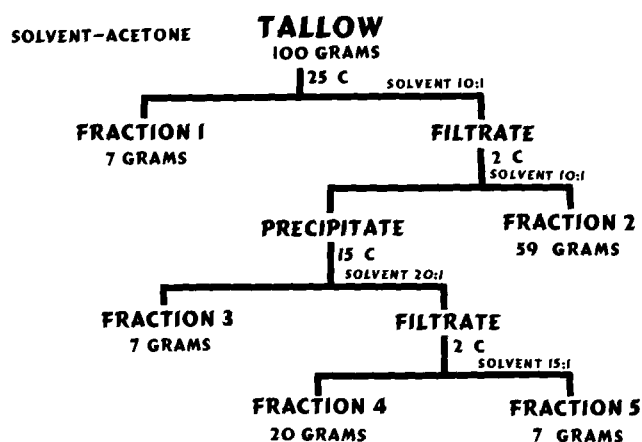


FIG. 1. Fractionation of tallow.

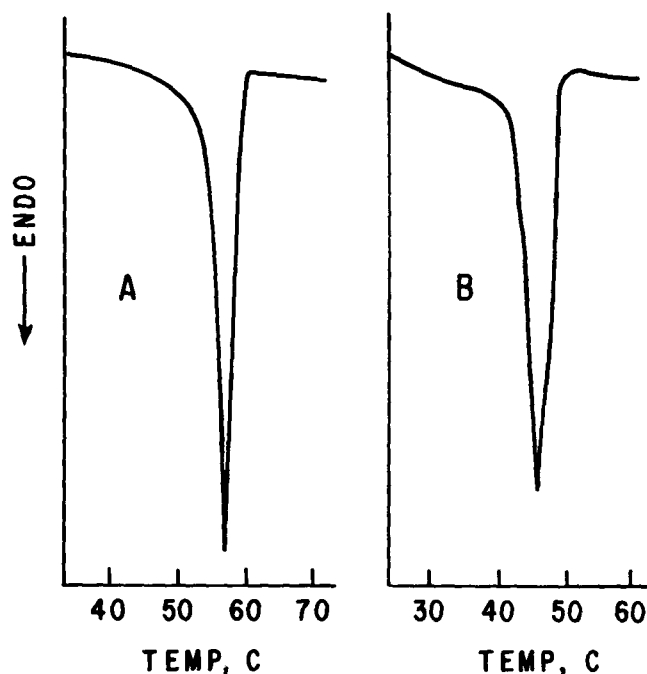


FIG. 2. Differential scanning calorimetry melting profile. (A) Fraction 1; (B) fraction 3.

TABLE III  
Fractionation of Tallow

Trial	Recovery, %	Fraction yields, wt%				
		Fraction				
		1	2	3	4	5
1	99.5	6.1	61.2	5.7	19.3	7.7
2	98.6	6.7	60.0	7.1	19.1	7.1
3	98.3	6.9	58.3	8.2	20.7	6.4
4	100.0	7.2	58.0	9.3	19.2	6.7
5	98.3	9.2	55.7	6.9	21.2	7.0
Average	98.9	7.1	58.6	7.4	19.9	7.0

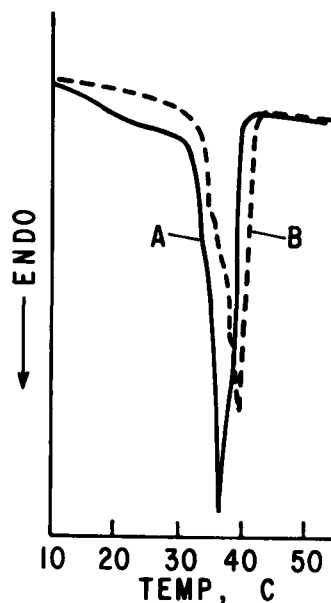


FIG. 3. Differential scanning calorimetry melting profile. (A) Fraction 4; (B) fraction 4a (fraction 4 + 10% fraction 3).

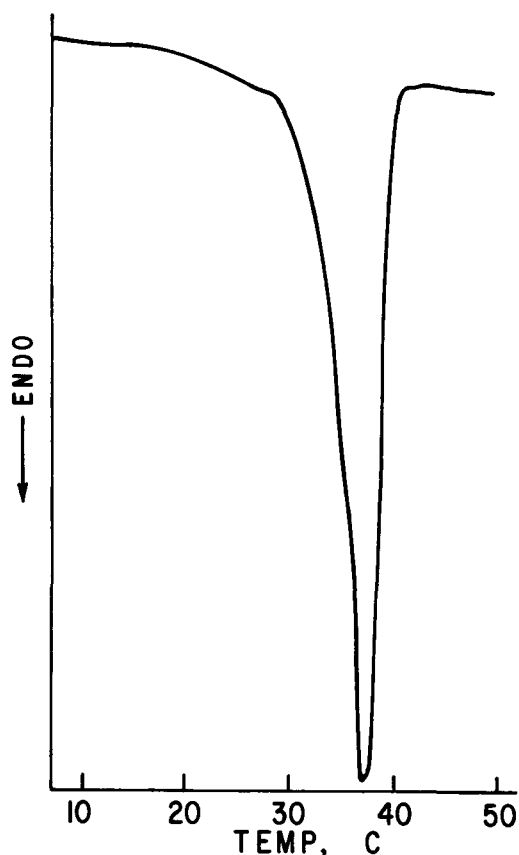


FIG. 4. Differential scanning calorimetry melting profile of cocoa butter.

TABLE IV  
Fatty Acid Composition of Fractions (wt%)

Fatty acid	Fraction				
	1	2	3	4	5
14:0	3.5	3.1	5.5	3.1	3.9
14:1	0.3	1.4	0.4	0.5	1.3
16:0	36.6	20.8	36.4	31.8	23.8
16:1	1.4	5.2	1.0	2.0	4.5
17:0	2.8	0.8	2.5	1.9	1.1
17:1	0.2	1.5	0.2	0.5	1.3
18:0	37.7	7.5	31.0	25.9	9.7
18:1	15.6	56.3	20.7	33.2	50.4
18:2	0.5	1.9	0.4	0.5	2.3
18:3	Trace	Trace	Trace	Trace	Trace
Others	1.4	1.5	1.9	0.6	1.7

and accounted for almost 80% of the total composition. These 37 glycerides are shown in Table II. Despite the great number of glycerides, five glycerides, POP, POS, POO, SOO and OOO were dominant. A comprehensive study of the glyceride composition of the tallow fractions will be reported in a later publication.

The tallow fractionation as outlined in Figure 1 was designed to separate conveniently the tallow into solid, semisolid and liquid glyceride fractions. The procedure was selected after numerous experiments in which different conditions of crystallizations of the tallow were employed. The yield and thermal properties of the semisolid fraction were a main consideration in the selection of the final procedure. The recorded melting profiles were compared with commercial products such as cocoa butter, confectionery hard butters and salad oils. A more detailed study of the thermal properties of the tallow fractions will be reported at a later date.

The reproducibility of the fractionation procedure is shown by the fractionation data of Table III. In five successive trials, each of 800 g, the total recovery was an average of 98.9%. The yield of the largest fraction (fraction 2) varied  $\pm 2.8$  unit per cent and the semisolid fraction (fraction 4) range was  $\pm 1.1$  unit per cent. The fatty acid composition of the fractions is shown in Table IV. These data are the average values obtained from the analyses of pooled fractions. In general the individual fractions pooled had almost identical fatty acid compositions.

Fractions 1 and 3, each at ca. 7%, were solid fractions and were crystalline when isolated. Their fatty acid compositions differ mainly in the amounts of stearic and oleic acids, with fraction 1 having the higher stearic acid content and fraction 3, the higher oleic acid content. The composition of the fractions was reflected in their thermal behavior as shown by the differential scanning calorimetry (DSC) melting profiles of Figure 2. Although fraction 1 was higher melting, the profiles were similar, and for many purposes these fractions could be combined into one solid glyceride fraction. The solid glycerides would be useful in any application where high melting glycerides are required. Since they resemble closely the hydrogenated stearines in melting characteristics, their obvious use would be as hardening fat in shortening and margarine formulations. In these formulations they could be used to control plasticity and to increase the plastic range without the expense of hydrogenation. In considering uses for beef fat or beef fat fractions, we have purposely avoided the inclusion of hydrogenation as a means of modifying the physical properties. While hydrogenation produces remarkable changes in the nature of fatty materials, one of the complicating factors of the process is the formation of a high percentage of isomeric monoenes with properties different from those occurring naturally. Recently, in the lay press and to some extent in the scientific press, the nutritional and biochemical aspects of isomeric acids have

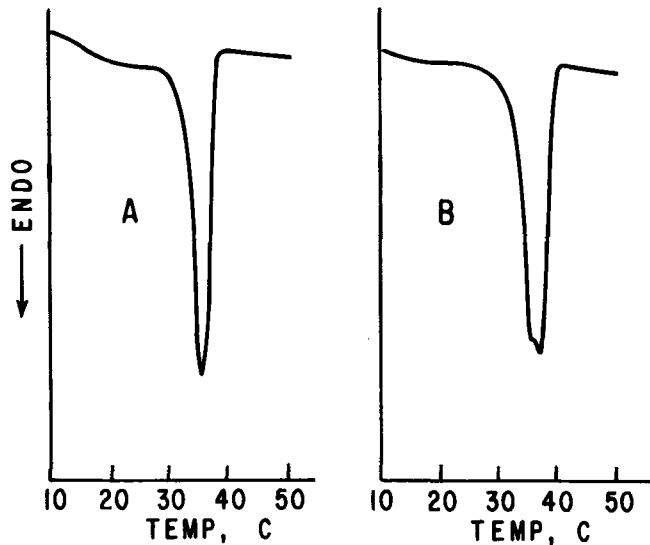


FIG. 5. Differential scanning calorimetry melting profile. (A) fraction 4a + 5% cocoa butter; (B) fraction 4a + 50% cocoa butter.

been questioned (14,15). The beef tallow glycerides of this study contained only ca. 4% of naturally occurring *trans*, calculated as elaidic acid. The principal fractions had the following average *trans* content: solid, 3.7%; liquid, 4.3%; and semisolid, 3.2%. Formulations using these fractions would contain only low percentages of naturally occurring *trans* isomers and would not be subjected to the same criticism as the hydrogenated fats.

Fraction 4 was a semisolid or plastic solid with a fatty acid composition of about one-third unsaturated acids, mainly oleic, which gave it a similarity to cocoa butter although the palmitic-stearic acid ratio was reversed. The DSC melting profile of the fraction is shown in Figure 3 and it compares favorably with the melting profile of cocoa butter shown in Figure 4. Since melting is characterized by the large downward deflection of the curves, the similarity in melting behavior of the two materials is evident. Both begin to melt substantially above room temperature and melt rather sharply and completely at body temperature (37.0 C). This is one of the properties of cocoa butter that makes it desirable as a confectionery fat. Fraction 4 resembles cocoa butter in glyceride composition in that it is composed primarily of 2-oleo disaturated glycerides of palmitic and stearic acids. Fraction 4 was ca. 1.5% trisaturated glycerides, 90% disaturated glycerides and 8.5% monosaturated glycerides. According to Jurriens (12) cocoa butter is 2.2% trisaturated glycerides, 84.6% disaturated glycerides, 11.6% monosaturated and 1.6% trisaturated glycerides. For some applications as a coating or confectionery fat, higher melting characteristics may be required than those exhibited by fraction 4. By blending increments of fraction 3 with fraction 4, the melting range of the semisolid fraction can be raised effectively. The addition of 10% of fraction 3 to fraction 4 raised not only the melting range but in fact improved the entire melting characteristics as shown by the DSC melting profile of fraction 4a in Figure 3.

One of the problems of the confectionery industry has been to obtain fats that could be blended successfully with cocoa butter. Many fats when mixed with cocoa butter form a mixture that has a lower melting point than either component and in many cases, a broader melting range. Such behavior probably intensifies the problem of chocolate "bloom." Fraction 4a can be mixed with cocoa butter in wide proportions without seriously altering the melting characteristics. Figure 5 shows the DSC melting profile of fraction 4a with 5 and 50% cocoa butter. Both mixtures showed little evidence of premelting and followed a melting

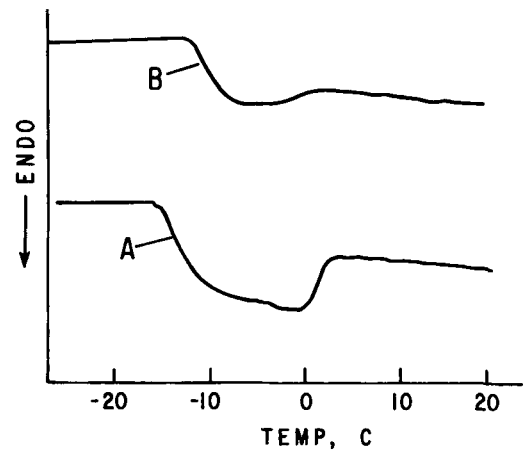


FIG. 6. Differential scanning calorimetry melting profile. (A) Fraction 2; (B) commercial salad oil.

cycle similar to that exhibited by cocoa butter.

The liquid glyceride fractions 2 and 5 were similar in their characteristics. The fatty acid composition of fraction 2 was ca. 6% higher in oleic and had slightly less palmitic and stearic acids than fraction 5, but for many uses they can be combined. The liquid glycerides had a composition estimated to be 10% disaturated glycerides, 70% monosaturated glycerides and 20% trisaturated glycerides. Fraction 2 had thermal characteristics much like commercial salad oil. Figure 6 compares the DSC melting profiles of the oil fraction and a commercial salad oil after both were cooled to -15 C followed by programmed heating at 10 C/min. The commercial salad oil was completely melted at ca. 0 C, while the tallow oil melted ca. 2-3 degrees higher. The unmodified fraction 2 had a cloud test of -1 C and a cold test of 3 hr at 0 C. It remained liquid at 6.7 C (44 F) but solidified overnight at 4.4 C (40 F). When mixed with a high linoleic commercial salad oil at the 40% level, an oil of excellent cold stability was produced which had a cold test of over 16 hr at 0 C.

The original tallow had a light color and a mild beef-like odor. The color and odor were concentrated in fraction 2 by the acetone crystallization. This produced an oil with a color similar to butter-oil and a stronger beef-like odor. When the fraction was steam deodorized at 1 mm Hg pressure at 180 C for 1 hr in the presence of 1% calcium hydroxide and 1/4% activated charcoal, a neutral, bland, odorless and lightly colored oil was produced.

The deodorized, neutral oil fraction is a high quality stable product containing little *trans* isomers and only traces of glycerides containing linolenate moiety. Its quality and composition compare favorably with many refined commercial oils. For example, it has several advantages over one of the newer imported vegetable oils, the liquid oil fraction produced by the hexane fractionation of palm oil (16). It is lighter in color and has less free acidity. The fatty acid composition shows it contains less palmitic, less linolenic and over 50% more monoene acids.

At room temperature, fractions 1, 3 and 4 were snow white in color, almost odorless and contained no free fatty acids. When melted, they had a very light yellow color.

Both the liquid and solid glyceride fractions have many potential uses in the edible oil and fat industry. It is beyond the scope of this paper to enumerate them all. Some of the obvious would include the use of the liquid fraction, alone or compounded with other oils, as a base for salad oils, frying and cooking oils, margarine oils, fluid shortenings and mayonnaise, and combinations of the liquid and solid fractions in plastic shortenings, margarines, simulated dairy products and specialized bakery products.

The semisolid glyceride fraction possesses many of the properties required for multipurpose confectionery and

bakery fats. Its thermal characteristics indicate that it is compatible with cocoa butter in wide proportions. It is neutral and bland in flavor, and low in polyunsaturates which should give it good oxidative stability.

The solid glyceride fractions will probably find their widest use as hardening fats to control the solids content or solids-liquid ratio in shortening and margarine formulations. As hardening fats in margarines, they should lessen the tendency to graininess, because they are complex mixtures of both trisaturated glycerides of palmitic and stearic acids and oleo disaturated glycerides of palmitic and stearic acids. The problem of graininess in margarines is resolved, as Wiedermann (17) points out, by using a hardening fat with such a multiplicity of components.

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