Animal Fat Raw Materials

G. MAERKER, Eastern Regional Research Center, Agricultural Research, Science and Education Administration, USDA, 600 East Mermaid Lane, Philadelphia, PA 19118

ABSTRACT

Over six billion pounds of tallow and grease are produced yearly in the United States, and almost 90% of these animal fats are utilized in feeds and as raw materials for industrial chemicals – both domestically and abroad. The fatty acid profile of an animal fat is a function of the kind of animal from which the fat was derived, as well as the breed, age, and diet of the animal. Impurities in the fat determine its grade and depend primarily on this history of the fat as well as on external contaminants which may have been added inadvertently.

INTRODUCTION

In recent years the world's production of fats and oils has increased at an average annual rate of ca. 4% (1) and is estimated to reach a total of 55 million metric tons in 1979 (see Table I). The 6 million tons of tallow produced in the world constitute only ca. 11% of the total supply of fats and oils, but, since tallow is the largest single source of industrial fatty acids, it deserves attention at this short course.

The principal animal fats are butter, tallow, and lard, the latter two being byproducts of the meat packing industry. Lard is an edible fat obtained from hogs, and edible tallow is usually derived from beef fat. Inedible tallow, also known as industrial or technical tallow, includes tallow and greases and often contains fats derived mainly from cattle but also from hogs, sheep, and poultry. The distinctions between edible and inedible tallow are based on hygienic and regulatory considerations rather than on chemical differences. To be classified as edible, the tallow must be derived from clean, sound tissues from carcasses of animals that were in good health at the time of slaughter. Furthermore, the production of edible tallow must proceed under hygienic conditions and under constant regulatory supervision. Only ca. 8% of the tallow produced in the United States, or ca. 0.25 million tons, is classified as edible.

In contrast to edible tallow, the inedible material is classified and traded in various grades in which minimum melting point (titer) and maximum color, free fatty acid content, and MIU (moisture, insolubles, unsaponifiables) are specified rather than origin. Materials having a titer of 40 C or above are tallows, while those that have lower titers are greases. The highest grade tallow (extra fancy) has a minimum titer of 42.5 C, while some softer greases have titers as low as 36.0 C. The prices of all commodities have a tendency toward periodic fluctuations. That this is also true of the fats and oils can be seen from Figure 1. Only four fats and oils are shown in this figure, but if we were to plot others, they would follow the same peaks and valleys over the years. This is so because the major fats and oils are fairly similar in their major composition, and there is a good bit of interchangeability between oils for various uses. An interesting fact that emerges from this figure is that inedible tallow has been and continues to be the lowest priced fat on the United States as well as on international markets, and this is one of the reasons that demand for inedible tallow continues to be brisk.

To the producer of fatty acids, the origin, composition, and quality of the raw material used has a bearing upon the composition and quality of the fatty acids that can be produced from it. Composition of animal fats depends on a number of factors, such as source animal, history of the animal (breed, age, sex, feed), history of the fat, and external contaminants.

TABLE I

World Oil and Fat Production (1)

Source	1979 Estimate in million tons	Percent
Field crops	30	55
Animal fats	15	27
Tree crops	9	16
Marine oils	1	2
Total	55	100

The principal components of all animal fats are triglycerides, which are esters of fatty acids and the triol glycerol. With very few exceptions, we know very little about the specific triglycerides present in fats, except that they are numerous. When our interest focuses on the fatty acids themselves, we simplify the analytical problem by converting the triglycerides to methyl esters and analyzing these by some chromatographic procedure. This gives us an idea of the relative amounts of fatty acids present, not only in the triglycerides but also in other components of the fat. The fatty acid composition of a very large number of tissues has been determined over the years, from microorganisms through insects and marine and land animals through human lipids. Not only the depot fat but also the lipids present in animal and human organs, body fluids, structural parts, and other components have been analyzed, and their principal fatty acid compositions have been recorded. The data of Table II illustrate the type of information available. Even more detailed data on animal and plant tissues can be gleaned from Hilditch and Williams (3), and animal fats of industrial importance are discussed in Bailey's Industrial Oil and Fat Products (4). The development of gas chromatographic methods during the past 15-20 years has aided tremendously in advancing the state of the art of fatty acid analysis. In fact, the composition of lipids can be measured more precisely and more rapidly now than that of any other natural product. Furthermore, the details of information available on fatty acid composition are still evolving rapidly. Only a few years ago we were quite satisfied to determine the 10-15 principal fatty acids present in beef lipid with some precision. Recent work by Slover and Lauza (5) demonstrates the presence in beef lipids of 80-100 fatty acids and gives identification for

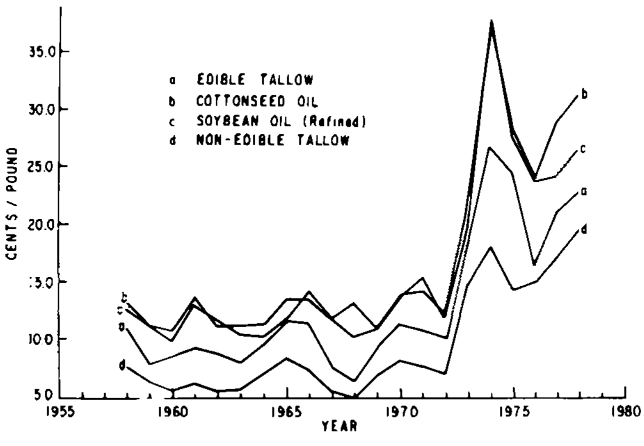

FIG. 1. Prices of fat and oils, 1958-1978.

TABLE II

Major Fatty Acids of Some Animal Depot Fats, wt % (2)

	14:0	16:0	18:0	16:1	18:1	18:2
Frog	4	11	3	15	52	52
Crocodile	3	27	5	7	34	17
Chicken	1	27	5	7	46	14
Rabbit	7	32	5	5	28	19
Horse	5	26	5	7	34	5
Hippopotamus	4	27	21	5	38	3
Camel	5	31	31	4	28	1
Lion	5	29	18	2	40	—
Human	3	23	4	8	45	10

69 of them (see Fig. 2). The GC spectrum is obviously quite complex, and adequate evaluation of the data requires computer capability. In passing, it is interesting to consider that the 80 or so fatty acids seen clearly in such a spectrum represent a possible total of over 500,000 triglycerides if random distribution is assumed.

To the producer of fatty acids, such a detailed analysis of the composition is of little importance. He is more likely to be interested in the gross composition of tallows illustrated in Table III. But even analyses such as the one shown here must not be taken literally, but should be considered illustrative only. The information that we can derive from this table is that the three tallows shown here contain more monoenoic C-18 acid than any other fatty acid, and that in beef tallow palmitic acid is more plentiful than stearic, while in the sheep-derived fats the opposite is true. Meanwhile, we are also aware that each sample of beef tallow, or of mutton tallow, will differ slightly in composition from the one we analyzed yesterday, that the composition of the fat taken from any particular animal will differ depending on the part of the carcass from which it is taken (6), and that when we are talking about the monoenoic acid 18:1 we are discussing a material that is predominantly oleic acid but also contains perhaps as much as 10-15% of positionally and/or stereochemically isomeric fatty acids.

Several past studies indicate (3,4) that the composition of animal fats varies as a function of geographic location, breed, age, sex, and feed of the animal. Many of these studies were carried out before gas liquid chromatography came into widespread use, and there may be some question as to the reliability of their quantitation. At any rate, in the production of fatty acids most of these variables are fairly inconsequential, since the raw materials are normally composites of various sources, and therefore individual variations are minimized. One variable which does have some significance, especially in nonruminants, is feed and its seasonal changes in composition. This effect of feed can be seen particularly in pork fat which varies considerably in hardness and in iodine value with the degree of unsaturation of the dietary fat (7). On the other hand, the hardness of beef fat is fairly independent of the degree of unsaturation of the feed, because of the ability of the rumen to hydrogenate polyunsaturated fatty acids. A variation in fatty acid chain length in beef fat as a function of feed variation can, however, be observed. The linoleic acid content of beef fat has been increased on an experimental basis by feeding beef a polyunsaturated oil, e.g., safflower oil, encapsulated in casein cross-linked with formaldehyde (8).

It has been mentioned earlier that the principal components of most fats and oils, including tallow, are triglycerides. These are converted to the free fatty acids or their soaps by methods that will be the subject of other papers in this short course. However, it will be helpful to consider the animal sources of the fats and their further treatment to convert them to the tallows and greases of commerce.

Animal tissue containing fat is converted to tallow and grease by a process called rendering. Basically, rendering is a procedure by which lipid material is separated from meat tissue and water under the influence of heat. There are two principal methods by which this is accomplished on an industrial scale. In the wet rendering process the animal tissue is placed in an enclosed pressure vessel, and superheated steam is injected to provide both heat and agitation. The mixture is cooked at 230-250 F for 3 to 6 hr. At the end of this period, the mixture settles into three phases: a top fat layer which is drawn off, an intermediate water layer, and a bottom phase consisting primarily of proteinaceous material. The dry rendering process was developed in the 1920s (9) as a logical extension of the earlier "cook and press" kettle rendering procedure. Since the original animal tissue contains considerable amounts of water and since it is the objective of the rendering process to separate the fat from the water and also from the bones and proteins, it was logical not to add further amounts of water to the mixture. In the dry rendering process, then, the fatty tissue is heated in jacketed containers, mechanical agitation is provided, and the water is removed either at atmospheric or at reduced pressure as it is freed. Even more modern rendering plants feature a continuous rendering process, highly sophisticated air and water pollution prevention equipment, and automated operation. One such plant, recently described (10), is capable of handling 3 million pounds of raw material each week. Yet more efficient methods of rendering, e.g., those featuring microwave heating (11), are being considered for installation in future plants.

Since the rendering process is primarily a physical separation procedure and since relatively little refining is

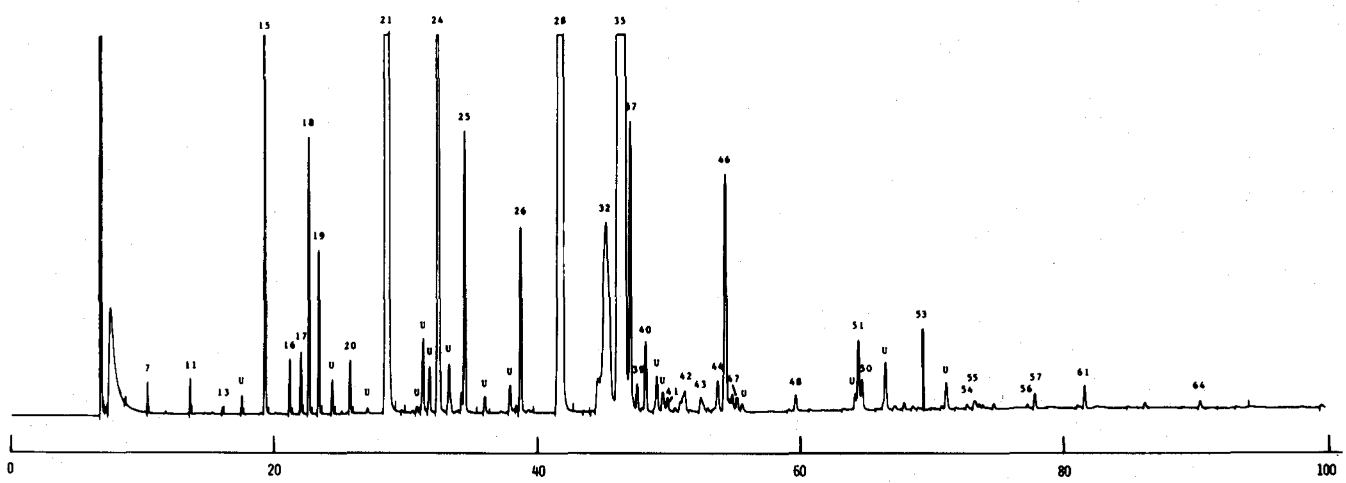

FIG. 2. Fatty acid methyl esters of beef lipids (4).

TABLE III

Composition of Tallows wt %

Fatty acid	Beef	Lamb	Mutton
14:0	4	3	4
16:0	27	22	23
16:1	5	3	3
18:0	14	31	28
18:1	42	35	37
18:2	2	3	1
Others	6	3	4

TABLE IV

United States Renderers' Raw Materials/Production – 1976 (12)

Source	Tallow and grease (Tons 000)	%
Beef	1532	42
Hogs	750	21
Lambs/sheep	19	NS
Poultry	258	7
Outdated consumer cuts	11	NS
Restaurant grease	718	20
Hide and trim fleshings	138	4
Dead stock	243	6
	3669	

TABLE V

United States Inedible Tallow and Greases 1976 (13)

Apparent production (000 tons) 2741

Disappearance

	(Tons 000)	Percent	Percent of domestic use
Export	1295	47.3	---
Animal feeds	635	23.2	44.0
Soap	333	12.1	23.0
Fatty acids	347	12.7	24.0
Lubricants	58	2.1	4.0
Other	72	2.6	5.0
	2740	100	100

carried out on technical inedible fats, it is clear that the raw materials that the renderer uses to a large extent determine the composition of his product. There are well over 900 rendering plants in the United States, and for any one of these the mix of raw material sources is likely to be a bit different than that of others. In general, however, there are four principal sources from which the renderer obtains his raw materials: a) Packing house byproducts. These may contain adipose (subcutaneous fat), organ fats, offal, bones, and even hide trimmings. b) Butcher shop trimmings. To a large extent these are adipose and intermuscular fats, but they also include much bone, cartilage and outdated meat cuts – the latter often still in their plastic display packaging material. c) Restaurant grease. This can be quite varied in composition, depending on the type of food operation from which it originates. d) *Fallen animals.* In certain parts of the country, diseased and fallen animals present a disposal problem that is handled by the local renderer. In recent years the "certified" tallow grade was introduced, primarily for the benefit of some foreign tallow buyers. "Certified tallow" is guaranteed not to contain fat from diseased or fallen animals.

We can gain a perspective of the relative importance of

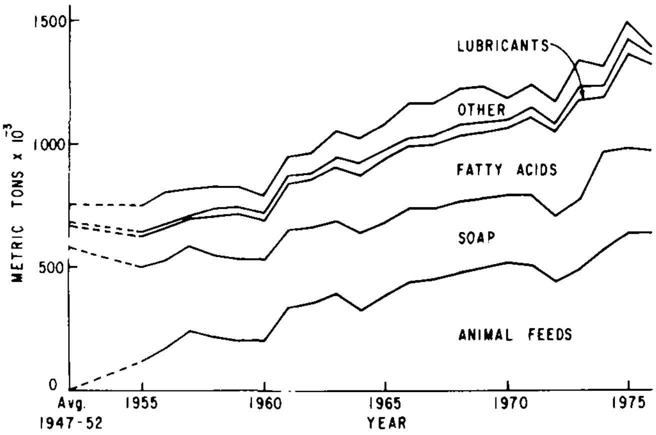

FIG. 3. Tallow nonfood uses in the United States.

various rendering raw materials from figures published in the Spectrum (12), a yearly publication of the National Renderers Association (Table IV). The production total of 3.7 million tons (8 billion pounds) shown here is considerably higher than the 6.6 billion pounds reported by USDA, apparently because the Department of Commerce, which collects the data for USDA, does not include the production of restaurant grease in its figures. Be that as it may, the relative sizes of these sources are of greater interest and of importance than their absolute amounts.

Given the variability of the raw material sources, it is not too surprising that there is a whole range of tallows and greases which differ not only in their degree of unsaturation but also in the degree of abuse to which they have been exposed, either before or after rendering. In general, the hardness of a fat bears an inverse relationship to its amount of unsaturation. There are two reasons for this. One is that the unsaturated fatty acids, and hence their triglycerides, melt at lower temperatures than the saturated acids. The other reason is that the double bonds of unsaturated fatty acids represent vulnerable areas subject to chemical, and especially oxidative, attack.

To be thorough we should mention a few of the non-triglyceride components one normally finds in animal fats, although they occur in fairly low concentration. The polar lipids are often compounds in which glycerol or the amino alcohol sphingosine is combined with phosphoric acid and a base. These types of compounds are normal cell wall constituents, and their occurrence in fats rarely exceeds 0.07%. Another group of compounds is usually classified under the term nonsaponifiables, i.e., they are stable under boiling KOH in ethanol. Among these are the sterols, particularly cholesterol, fatty alcohols, hydrocarbons such as squalene, carotenoids that have been introduced through the animal's feed, and others. The amount of unsaponifiables in tallow normally is in the 0.2-0.4% range. The free fatty acid content of tallow is one of the indicators used to establish grade. Free fatty acids in fats and oils occur as a result of hydrolysis, either chemical or enzymatic, of glycerides and can be expected to be accompanied by a corresponding amount of mono- and diglycerides. Free fatty acid may range from <1% to 10-15%. Air oxidation of fats, particularly of their polyunsaturated fatty acids, results in the formation of hydroperoxides, which can be measured by titration. The hydroperoxides slowly degrade to alcohols, which together with ketones, constitute further impurities that may be present.

Impurities may also be introduced during the collection and handling of the fat and tallow. Among the impurities that are of importance to the producer of fatty acids are polymeric materials, such as polyethylene. These polymers stem from the packaging materials used for retail meat cuts as well as from the liners of cans used by butcher shops to collect fat and meat scraps. When these polymers enter the rendering process, they disperse in the tallow and are difficult to remove. During the subsequent use of tallow in fat splitting, the polymers are reported to accumulate in the splitting towers and present a hazard there.

Finally, we should take a quick look at uses that are made of tallow. The data for 1976 are given in Table V, and domestic use trends over the past twenty years are shown in Figure 3. It is evident that the United States exports almost as much tallow as it uses at home, and, in fact, the United States product represents about three-fourths of the world trade in tallow. At home, by far the largest single use for inedible tallow is in animal feeds, especially in formulated beef and poultry feeds and in pet foods. Fatty acids and soaps consume about equal amounts. Before petroleum-based detergents became popular in the 1950s, soap constituted the largest single use for industrial tallow. With increasing prices and decreasing availability of petroleum, the day may come again when tallow will become an important raw material base for soap-derived detergents.

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New Fatty Acids from Outer Space

H.BROWN, Finetex, Inc. 418 Falmouth Avenue, Elmwood Park, NJ 07407

ABSTRACT

A recent space exploration has revealed that in the far reaches of outer space matter attains a state of complete weightlessness. Herman Brown, reporting on his latest spaced-out venture, indicates that weightless fatty acids obtained from the Superba Galaxy are ideally suited for the manufacture of improved food additives. What a magnificent way to provide the diet-control foodstuffs of the 21st Century!

(**Course Chairman's Note**: Fully cognizant of the results of Orson Welles' famed radio broadcast, where he promoted the idea that the Martians were engaged in a real earth invasion, we find it necessary to state unequivocally: *as far as we know, there are no fatty acids in outer space.* Furthermore, if there *is* organic matter within the meteorites that enter the earth's atmosphere, it is probably *not* in the form of fatty acids. Publication of the above abstract in our preliminary program occasioned dozens of inquiries on this subject. Mr. Brown's paper at the Short Course was a hilarious spoof on this subject as well as a few others. We include the abstract here to complete the entire story of "AOCS at Tamiment.")

Fat Splitting

N.O.V. SONNTAG, Southland Corporation Chemical Division, First Continental Bank Building, Suite 400, 5801 Marvin D. Love Freeway, Dallas, TX 75237

ABSTRACT

Fat splitting, particularly the continuous, high pressure, countercurrent hydrolysis of fats and oils, typified by the Colgate-Emery or modified processes, represents the technological cornerstone for today's American fatty acid industry. Internationally, other methods such as Twitchell or batch autoclave "medium-pressure" catalyzed or uncatalyzed splitting are still important. All industrial fat splitting methods have as their objectives the attainment of a high rate of hydrolysis together with a high degree of completeness. This objective is achieved, more or less, by the proper optimum balance of: (a) use of excess water; (b) selection of appropriate combination of temperature and pressure to optimize the solubility of liquid water in the fat phases with or without use of suitable "water-in-oil" emulsifiers; (c) use or nonuse of acidic catalyst (rarely basic catalysts); and (d) removal of byproduct glycerol. Significant conditions and details in fat splitting by the important commercial processes are described.

Fundamentally, fat splitting is generally represented in all the textbooks as an oversimplified reversible chemical reaction consisting of adding H_2O to a glyceride to produce glycerine and three mols of fatty acids. Fat splitting, as might be expected, is far more complex than this simple reaction. Some idea of the overall complexity may be given by a consideration of the stepwise nature of fat hydrolysis from triglyceride to diglycerides to monoglycerides to fatty acids and glycerol. For practical purposes, the following facts enable us to discover the true nature of the fat splitting reaction: (a) water is increasingly soluble in di- and monoglycerides and in fatty acids than in the starting material triglycerides; (b) higher temperatures and pressures as shown in Table I increase the rate of hydrolysis as a