Use of Non-Food Fats in Animal Feeds[1]

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ONE of the most significant developments in the feed industry (1) during the past two years has been the rapid increase in the use of non-food animal fats (grease and tallow) in feeds. Estimates indicate that in 1952 only 10,000,000 lbs. of animal fat were used in feeds. At the close of 1953 animal fats were being used at an annual rate of about 200,000,000 lbs. At present, the estimated annual rate of consumption is close to 250,000,000 lbs.

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For many years the major part of these fats has been used in soap manufacture. Recently, as a result of technological developments, competitive materials from other sources have been introduced in the form of synthetic detergents. These products have found substantial acceptance for many uses previously served by detergents made from animal fats. A large increase in the production of tallow and grease also accompanied the increased competition. This resulted in an increasingly large surplus of production over domestic consumption during the last five years, as may be noted from Table I. While it was possible to dispose of the surplus on the export market, the price was unfavorable and resulted in a greatly depressed domestic price.

TABLE I

Tallow and Grease Production and Consumption

Year	Production	Consumption	Surplus
	(Million Pounds)	*(Million Pounds)*	
1943	1649	1759	—
1944	1943	1923	20
1945	1751	1839	88
1946	1658	1679	—
1947	2023	1882	141
1948	1940	1782	158
1949	2132	1666	466
1950	2272	1807	465
1951	2252	1660	592
1952	2318	1541	777
1953	2560	1839	721

Importance in National Economy

Efficient utilization of these fats is of great importance to the entire national economy. For many years the meat packing industry has sold the beef carcass on the wholesale market at a price equal to or less than the cost of the live animal. This has been possible because of efficient utilization of by-products and a sustained demand for such products. The prices paid for livestock are higher than would be warranted if there were no by-product recovery and if the price were determined solely by what the consumer is willing and able to pay for the edible products. Higher livestock prices stimulate increased livestock production. Thus the consumer and livestock producer, as well as the meat processing industry, benefit when maximum value is realized from by-products.

In addition to the tallow and grease produced by the meat packing industry, large quantities are produced by the rendering industry. The rendering industry performs an important service in the national economy by recovering useful products that otherwise would be wasted and would require expenditure of public funds for disposal in order to avoid public health hazards.

Reasons for Using Fats

Among the major reasons for the decision by feed companies to add stabilized fats to their feeds are the following:

1. *Increased palatability.* Many mixed feeds have a tendency to be dry and dusty unless fat-rich ingredients are used or materials, such as molasses and fish solubles, are present. Dustiness decreases palatability for pigs and chickens. When from 1% to 3% of fat is added to the feed, it overcomes dustiness and improves palatability.
2. *Decreased waste of feed.* Dustiness results in loss of feed during mixing, handling, and feeding. Animals waste dusty feed because it runs out of their mouths before they get it moist enough to swallow. When fed in the open, wind blows away considerable quantities of dusty feeds.
3. *Increased comfort of workers in the feed mixing plant.* The elimination of dustiness during handling and bagging of feed markedly improves the comfort of the worker.
4. *Improved appearance of the feed.*
5. *Decreased wear on mixing and pelleting machinery.*
6. *Ability to handle and ship in bulk.* This is important with dehydrated alfalfa and solvent extracted oil meals where bulk handling saves the cost of bagging.
7. *Increased feed efficiency.*
8. *Increased stability of Vitamin A.*
9. *Favorable price of fats vs. other energy feeds.*

Commercial Grades of Animal Fats

Animal fats commercially available for use in feeds are rendered from animal tissues accumulated during the conversion of livestock to meat. Raw materials of this type are classified as not suitable for human consumption, and, for this reason, greases and tallows rendered from them generally are termed "inedible." It should be remembered however that these fats are processed at sterilizing temperatures and, from all viewpoints, are quite suitable for use in animal feeds.

Inedible animal fats under established standards are separated according to titer (melting point) into two classes (Table 2). Those with a titer of 40°C. or higher are tallows while those with a titer of less than 40°C. are termed grease. (Tallows and greases are animal fats; they should not be confused with lubricating grease or any other product derived from petroleum.) Each class of rendered fat is divided further into grades established on the basis of free fatty

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acid content (FFA), and the FAC color maximum of the untreated and unbleached fats, and the amount of moisture and insoluble and unsaponifiable material (M.I.U.) present. Characteristics of the commonly recognized grades of animal fats are outlined in the following table:

TABLE II

Characteristics of Animal Fats

Fats	° C. Titer (minimum)	% F.F.A. (maximum)	% M.I.U. (basis)	F.A. Color Maximum Untreated and Unbleached
Tallows				
Fancy	41.5	4	1	7
Choice	41	5	1	9
Prime	40.5	6	1	13 or 11B
Special	40.5	10	1	19 or 11C
No. 1	40.5	15	2	33
No. 3	40.5	20	2	37
No. 2	40	35	2	No color
Greases				
Choice white	37	4	1	11
A, white	37	8	1	15
B, white	36	10	2	19 or 11C
Yellow	36	15	2	37
House	37.5	20	2	39
Brown	38	50	2	No color

Selection of Tallow or Grease Suitable for Feed

Animal tallows and greases are used for a number of manufacturing purposes, and the previously mentioned grades have become established as a measure of quality and suitability for such purposes. These grade standards were not devised to indicate the value of the fats in feeds and are not of major significance as far as suitability for use in feeds is concerned. Free fatty acid content, color values, and M.I.U. possess no particular meaning as applied to the use of fats in feeds. Under the circumstances established grades for tallows and greases are of importance to the feed manufacturer chiefly because they are the existing means of product identification and because they reflect the accepted standard of market values.

As has been stated previously, there do not appear to be any compositional or nutritional reasons why most of the grades would not be equally satisfactory in the formulation of feeds. On this basis, palatability and stability become the major considerations in determining acceptability of the different grades of fats. These factors are not covered in existing quality standards, and purchasers of fats for feeds find it necessary to establish their own standards of acceptability. The nature and condition of the raw materials charged into the rendering tank have an important bearing on the quality (including palatability and stability) of tallow or grease produced.

Siedler, Scheid, and Schweigert (26) compared the effect of different grades of stabilized grease and tallow when used at 3% and 6% levels in broiler rations. The following fats were used: fatty acids prepared from choice white grease, yellow grease, brown grease, prime tallow, and No. 2 tallow. The AOM values before addition of antioxidants ranged from 6 to 11 hours, and after stabilization with a mixture of BHA, propyl gallate, and citric acid from 47 to 107 hours. No differences in rate of gain or appearance of the broilers were noted with the different grades and levels of fat fed. Data on the amount of fat ingested and excreted showed excellent digestibility of all the grades of fat used. No difference was noted in the eating quality of birds fed choice white grease and those fed brown grease. All groups of birds were judged excellent in quality. The results show that properly stabilized fats are utilized equally well regardless of the free fatty acid content.

At the last annual meeting of the Poultry Science Association (July 26-29, 1954) Sunde reported the results of feeding choice white grease, yellow grease, brown grease, prime tallow, No. 1 tallow, hydrogenated fat, oleic acid, and stearic acid at a level of 5% in the ration. All products except the hydrogenated fat and stearic acid improved feed efficiency. They found that the acids from hydrogenated fats and stearic acid were not utilized by the chick. At the same meeting Carver reported similar results. These results indicate that the practice of completely hydrogenating fats impairs their nutritive value.

Importance of Stability Towards Rancidity

The importance of protecting the fat against development of oxidative rancidity cannot be over-emphasized. If the fat is not stable and becomes rancid, it may become unpalatable. But an even greater hazard accompanying fat rancidity is the reduction of the nutritive value of the feed. It is well known that oxidative rancidity in fats promotes destruction of Vitamins A, D, E, and some of the B complex. It has been shown that the disease of chicks, known as encephalomalacia or "crazy chick" disease, is a vitamin E deficiency and may be brought about by feeding highly unsaturated fish oils. Oxidation of the fish oils results in destruction of vitamin E. Scott (22) has shown that hock disease of turkeys is a vitamin E deficiency and that it can be prevented by using the antioxidant BHA to protect the vitamin E of the ration against oxidation.

Only those fats that can be adequately stabilized with a suitable antioxidant should be used in feeds. We believe that no fat, regardless of grade, should be used in feed unless it possesses an AOM stability of not less than 20 hours after treatment with a suitable antioxidant. Experiments (20) have shown that feeds, to which animal fats treated with suitable antioxidants have been added, remain free from rancidity for a year or longer.

Antioxidants for Stabilizing Animal Fats

The Federal Meat Inspection Service has issued regulations permitting the use in animal fats of limited amounts of a number of different antioxidants after the Federal Food and Drug Administration had indicated that, based on adequate toxicity tests, the substances were safe for use. Among those antioxidants approved by the Federal Meat Inspection Service the following are commercially available: butylated hydroxyanisole (BHA), propyl gallate, nordihydroguariaretic acid, butylated hydroxytoluene (BHT), and lecithin. The regulations permit the use of BHA, propyl gallate, nordihydroguariaretic acid, or BHT in amounts not to exceed 0.01%. These antioxidants may be used in combinations in which a total amount of any one antioxidant does not exceed 0.01% and the total amount of the combined antioxidants does not exceed 0.02%. An amount of citric acid or of phosphoric acid up to 0.01% may also be used with the antioxidants.

Studies by Neumer and Dugan (16) of the effect of antioxidants on fat added to feeds have revealed that the most effective in promoting stability in fats are the hindered phenolic types of antioxidants, which include BHA and BHT. Propyl gallate and nordihydroguariaretic acid, which are not hindered phenols, are not as effective in delaying rancidity in dry dog food to which the stabilized fat is added. BHT is effective but not quite as effective as BHA. The combinations of BHA and BHT show synergism, that is, the combination effect is greater than the sum of the effects of the two when used alone.

The combination of BHA with propyl gallate and citric acid in fat added to dry dog food (25) was found to increase the stability of vitamin A in the dry feed. BHT may have a comparable effect, but it has not been evaluated for this purpose. Such studies are now under way.

A technical grade of BHT is used in the petroleum industry. Experiments carried on in the American Meat Institute Foundation have shown that the technical grade is not suitable for use in edible animal fats since off-flavors and odors result in the foods prepared with the fats. We do not know whether the off-flavors and odors would develop in feeds.

Lecithin is not a very effective antioxidant for the stabilization of animal fats. Lecithin stabilized fats have not been evaluated for their effect on the stability of feed containing added fat.

Antioxidants for Which Only Limited Toxicity Data Are Available

Santoquin (6-ethoxy-1,2-dihydro-2,2,4-trimethyl quinoline) has been found effective for preserving the carotene content of dehydrated alfalfa meal. The Federal Food and Drug Administration has indicated that it has no objection to the use of Santoquin for stabilizing carotene for alfalfa that is to be used only for poultry. The toxicity of the compound has not been established for other animals. Santoquin is not a very effective antioxidant in delaying rancidity of animal fat. Thus Santoquin is not suitable for the stabilization of animal fats to be used in feeds.

Diphenyl-p-phenylenediamine (DPPD) has been recommended at fairly high levels for use in poultry feeds to control the incidence of nutritional encephalomalacia or crazy chick disease. The Federal Food and Drug Administration has indicated that it has no objection to the use of DPPD in the amounts of 125 parts per million in only poultry rations. In view of these facts we do not regard DPPD as suitable for general use in stabilizing animal fats in feeds. Much more extensive toxicity tests would be required before it should be used in feeds other than those for poultry.

In recent reports by Singsen it has been stated that the incidence of encephalomalacia (crazy chick disease) in chicks may be increased by the feeding of animal fats. Singsen has shown that the feeding of high iodine number fish oils (A and D feeding oils) induces encephalomalacia, but since the animal fats (grease and tallow) are relatively low in iodine number his assumption does not appear valid. More recently at the Poultry Science Association meeting (July 26-29, 1954) Potter from Singsen's laboratory reported that the addition of 8 per cent unstabilized yellow grease to the ration did not induce encephalomalacia. The addition of 1, 2 or 4% unstabilized yellow grease, along with 1 per cent A and D oil, lowered the mortality to 35 to 38% from 50% when A and D oil was used without yellow grease.

Di-tertiary-amyl hydroquinone and di-tertiary-butyl hydroquinone have been found effective in stabilizing carotene in alfalfa. However they have little, if any, effect in stabilizing animal fats. Furthermore these compounds have not been thoroughly tested for toxicity. For those reasons they cannot be recommended for stabilizing animal fats in feeds at the present time.

Stabilization of Animal Fats During Rendering

Stabilization of the fat by addition of the antioxidant BHA in combination with citric acid to the rendering tank has been found successful in a number of cases. BHT or a combination of BHA and BHT may also be satisfactory for this purpose, but it has not yet been adequately studied. The combination of BHA and BHT appears to be promising. To our knowledge, other antioxidants have not been tested for this purpose.

Effect of Stabilized Animal Fat on Stability of Vitamins in Feed

Siedler and Schweigert (25) found that the stability of vitamin A (a fish liver oil) in the feed during storage at room temperature was increased when 6% of choice white grease stabilized with an antioxidant containing BHA was added to the feed. Studies are now under way in our laboratories to determine whether animal fats stabilized with BHT will increase the stability of vitamin A in feeds. At present we have no information on this matter. Hare (7) found that the addition of fat to feeds increases the utilization of vitamin K.

Results of Feeding Tests

Siedler and Schweigert (2) (24) found the rates of gain of young cocker spaniel pups when 4, 6 and 8% of fat were added to an experimental ration and 6% to a commercial dog food, were equal to or slightly superior to those obtained without addition of fat. Maintenance, reproduction, and lactation of cocker spaniel dogs fed rations with and without the addition of 4 or 8% of fat were observed. Reproduction and rate of gain of pups were improved by an addition of 4% of fat to the ration. The addition of 4 or 8% of fat increased the feed and caloric efficiencies.

Gutteridge (6) reported that the addition of 5% of animal fat to a poultry ration increased the rate of gain and improved the quality of the carcass. Slinger *et al.* (27) found that the addition of soybean oil to the ration of chicks increased growth slightly and improved the feed efficiency. Siedler and Schweigert (23) added 2, 4, 6, and 8% stabilized white grease, respectively, to a practical basal ration fed to growing chicks. Rate of gain when fat was added was equal to or slightly higher than when the basal ration was fed. Feed efficiency increased with the increase in level of fat.

Yacowitz (31) added lard, cottonseed oil, or soybean oil to chick rations and obtained results similar to those of Siedler and Schweigert. He found an average increase in feed efficiency of 9.5% when 2.5 and 5% of cottonseed oil or lard was included in the ration.

Donaldson (University of Maryland) recently reported that, in a 10-week feeding test involving 8,000 broilers, the use of 4% added fat resulted in a saving of approximately 1,920 pounds of feed.

Lillie *et al.* (12) found that up to 10% of lard in the ration can be fed to hens without decreasing egg production. The rations containing added fat were about 16% more efficient than similar rations without added fat.

In an experiment with laying hens Hill (Cornell University) found that the feed efficiency was improved when 2.5 or 5% of fat was added to the ration. He found the tallow to have a value of 12.5c per pound.

Sunde (28) fed white grease, prime tallow, or soybean oil at levels of 2.2 and 5%. No consistent increase in rate of gain was observed with chicks, but a slight improvement was noted when prime tallow was fed to turkey poults. Feed efficiency was increased with both chicks and turkey poults.

Klose *et al.* (9) found that the addition of tallow to the feed results in increased resistance of the turkey fat to oxidative rancidity.

Hillier found that the addition of animal fat to rations fed to pigs from weaning to 225 lbs. weight increased the feed efficiency. About 15% less feed was required per unit of gain by pigs on the high fat rations. Perry and Beeson (17) also found a marked increase in feed efficiency when from 6 to 10% of lard was added to the ration fed to swine.

Barrick *et al.* (3) obtained an increased rate of gain and improved feed efficiency when 10% of fat was added to the ration with 10-week-old pigs. Animal fats were worth 10c per pound with corn at $1.68 per bushel. Krop *et al.* obtained similar results when 10 and 15% of beef fat tissues were added to the ration.

Willey *et al.* (30) found that the addition of vegetable oils to a low-fat ration increased the feed efficiency and rate of gain in fattening cattle. Matsushima and Dowe (13, 14, 15) obtained cheaper gain with beef cattle when pellets containing beef tallow were used to replace a part of the corn in the ration. Barrick *et al.* (2) found that fats can effectively substitute for part of the grain in fattening rations for steers. They obtained more rapid gains and increase in feed efficiency when 5% of animal fat replaced 6% of corn in the ration. Schweigert and Wilder (21) found that animal fat fed at a level of 1 lb. per day per animal to fattening steers was equivalent to 2½ lbs. of corn. Kammlade and Butler (8) found that lambs fed a ration containing 5% of stabilized animal fat made the largest, most efficient, and cheapest gains and had the highest dressing percentage and carcass grades.

Value of Added Fats in Feeds

From a nutritional standpoint, fats are primarily sources of energy. From that viewpoint they must complete with the cheapest non-fat source of energy, which is usually corn. The caloric value of corn is 3.5 per gram, and of fat 9. With the price of corn 3c per pound, the minimum value of fat is 7.5c per pound. On the basis of digestibility 90 to 95% for fat and 80% for corn, the minimum value of fat as a replacement for corn is 8c per pound.

There is considerable evidence from feeding tests that increased feed efficiency may prove to be an important additional value. Rice *et al.* (18) estimated the value of fat in experiments carried out in their laboratories, and from experimental data from other laboratories reported in the literature. They calculated the difference in retail price of 100 lbs. of feed required to produce the same gain when no fat was added to the feed and when fat was used to replace a part of the corn in the feed. On this basis they found values of 5 to 16.6c per pound of fat with broilers; 4.2 to 16.6c for ducks; 14.2c for turkeys; 4.5c for swine; and 12.5 to 18.3c for fattening steers.

Also, avoidance of dustiness which results in discomfort to workers and appreciable loss of feed may prove to be of significant value. If such feeds as dehydrated alfalfa could be shipped and handled in bulk instead of in bags, there would be an additional value.

Methods of Adding Fats to Feeds

Wilder (29) has discussed fully the methods and equipment used in storage, handling, and mixing of fats into feeds. The actual mechanics of adding fat to feeds presents no major problems. Methods and equipment are determined by the specific production and mechanical requirements of the individual feed plant.

Animal fats at a temperature of 120°F. usually will be found to mix readily with the feed ingredients in the summer time. In the colder winter months 160°F. will usually be found satisfactory although in extremely cold weather 180° or 200°F. may be required.

The fat can be introduced into the feed with practically any existing type of feed mixers. Fat is one of the easiest liquids to mix into feeds because it is readily absorbed by most other feed ingredients.

A number of manufacturers produce specialized equipment designed for mixing liquid ingredients into feeds. All heating coils, pumps, and metering devices, as far as possible, should be made of metals that do not contain copper. Extremely small traces of copper promote oxidative rancidity in fats.

Available Supplies of Animal Fats

Ewell (5) recently made an extensive study of the production and utilization of tallow and grease. He concluded that by 1957 there will be an annual surplus based on cured usage of 1.1 billion lbs. and that unless new uses were found for the fats this level of surplus will be maintained for several years.

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Hydrolysis Methods

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THE hydrolysis of fats to fatty acids and by-product glycerine is practiced extensively, as we know, by many companies but by relatively few methods. For more than 100 years fatty acids have been produced on an intentionally commercial basis. At first prolonged boiling at fat and water was utilized; later sulfuric acid became the established catalyst. In the 1890's Ernst Twitchell developed the sulfonic acid catalyst bearing his name. Additional improvements in the acid catalyst have taken place since but no major change. Meanwhile attention was given to operation at higher temperatures and pressure even in this early period. While popular in Europe, batch autoclave operations did not make much headway in this country. In the last 25 years the availability of suitable materials of construction, notably the stainless steels, and a background of successful continuous operations in chemicals and in petroleum aided in the successful operation of the continuous countercurrent autoclave process.

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Hydrolysis Reaction

A brief discussion of the hydrolysis reaction itself should aid in the consideration of these methods. The general case of ester hydrolysis may be represented as:

$$RCOOR' + HOH \rightleftharpoons RCOOH + HOR'$$

In this particular case the alcohol is glycerine with three hydroxyls. The simplest glyceryl ester would be the monoglyceride:

$$\begin{array}{ccccccc} RCOOCH_2 & + & HOH & \rightleftharpoons & RCOOH & + & HOCH_2 \\ | & & & & & & | \\ HOCH & & & & & & HOCH \\ | & & & & & & | \\ HOCH_2 & & & & & & HOCH_2 \end{array}$$

Since fats are triglycerides, a series of three hydrolysis steps are required to obtain free acid and glycerine. Although there are three ester linkages in the triglyceride, there is no evidence for any one being especially reactive. Neither is there evidence for a marked difference in reactivity for mono-, di-, or tri-esters. Both di- and mono- are found in the product from hydrolyzing mixtures (7). The same catalysts and conditions favor the reverse reaction of esterification, which also proceeds stepwise. Therefore equilibrium yields all possible reaction products and intermediates. It is interesting to note that if the fatty acids are further removed from the reaction by formation of a salt, such as the formation of soap, there would be no reverse reaction and consequently little intermediate mono- and di-ester present. Unsaponified fatty material in a soap kettle shows up as predominantly triglyceride.

a) *Effect of Immiscible Phases.* With a simple ester such as ethyl acetate, all reactants and products are mutually soluble. In the case of long chain acids such as fats, the ester and the acid are miscible as are the alcohol and water, but the fatty acids are but very slightly miscible with water and glycerine. This both helps and hinders the design of satisfactory processes and equipment. Since water and fat, the two reactants, are but slightly soluble, reaction may take place either at the interface, in the water phase due to the slight solubility of fat in water, or in the fatty phase due to the slight solubility of water in fat. Reaction takes place much more readily in solution where both water and ester are freely available to each other than it does at a water-oil interface. Therefore the reaction due to the small mutual solubility of the two phases is more important than that taking place at the interface. Since the solubility of water in fat is considerably higher than that of fat in water, the fatty phase is the most important.

Furthermore water is much more soluble in monoglycerides and in fatty acids than in the tri-glyceride ester so that its concentration in the fatty phase increases as the reaction proceeds. A triglyceride which contains no free acid exhibits an induction period as shown in Figure 1 (8). A similar phenomenon is observed during kettle saponification of refined oils. This is not a problem with most low grade raw stocks, which always contain considerable free acid.

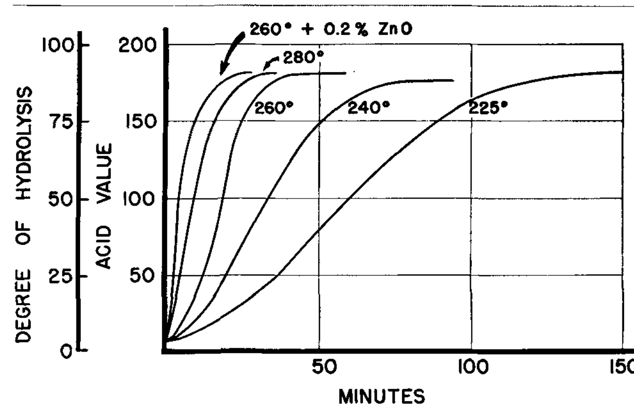

FIG. 1. Hydrolysis of beef tallow (8)

b) *Effect of Free Glycerine.* As fat is converted to fatty acid, the concentration of the reacting ester decreases and the reaction slows down. The amount of free glycerine is increasing and tends to suppress fur-