The Value of Fat as a Feedstuff[1]

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NUTRITIONALLY there has never been any reason to question the merit of fat as an ingredient in the food of man or animals. Fats are energy-rich, highly digestible, and palatable, as has been proved by countless tests with animals in laboratories and feedlots. However many things other than nutrition influence the selection of materials for use in feeds and help determine the over-all value of a feedstuff. These include:

a) Alterations of the physical characteristics, such as color, odor, texture, etc.
b) Palatability.
c) Effect upon the stability or "shelf life" of the feed.
d) The prejudice of feeders for or against a product, and
e) Price.

All of these factors are important, and unfavorable conditions in any may prevent use of a material in feeds. Price has heretofore eliminated fat as a feed ingredient, and as a result its many advantages have been overlooked.

Contributions of Fats to Feeds

In view of the many published demonstrations that fats are energy-rich materials and that they are readily utilized by animals, it is not necessary to elaborate upon this feature at this point. Other properties of fats are less well known.

Mash feeds have a tendency to be dry and dusty unless they include fat-rich feedstuffs such as meat scraps, tankage, expeller cottonseed or soybean meals, etc., or materials such as molasses, fish solubles, or protein hydrolysates which carry substantial percentages of water. When formulas are modified to include 1 to 3% of tallow, dust is no longer a problem. The seriousness of the problem for feed mixers is illustrated by Figure 1, which shows an operator filling bags with a dusty feed and with the same product containing 2% fat. This may seem like an extreme case, but feeds like these are on the market.

Excessive dust is objectionable to the feed manufacturer who does not like to blend and bag a dusty product, to the retailer who must store and handle it, to the farmer who gets billows of dust in his face as he empties the bags into bins, and to the animal which must eat a dry ration and breathe its dust. Some animals, pigs, and chickens especially, tend to waste excessive amounts of dry feeds simply because the feed runs out of their mouths before they get it moist enough to swallow. Also, if exposed feeders are located in windy areas, losses by blowing may be appreciable.

The addition of fat also improves the color and texture of many feeds, making them look "richer" and feel more moist. If mash feeds containing added fat are squeezed tightly in the hand, then released slowly, they tend to retain shape whereas dry feeds fall limply into a heap. The use of added fat makes feeds darker and more lustrous.

In some cases fat improves palatability. This is especially true with dry, dusty meals. A prime example of this is in dry dog foods. Animal fats carry flavors which dogs like, and fats have been added to several popular dog foods. Tests made with swine have also indicated preferences for feeds containing fat.

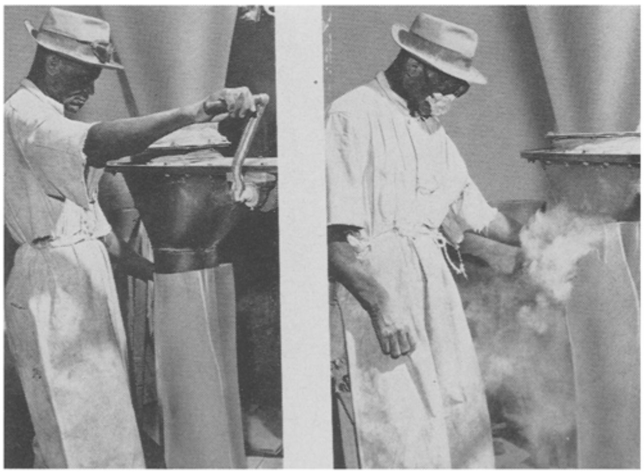

FIG. 1. Bagging of feed with and without added fat.

It is possible to avoid excessive dryness and to achieve other desirable properties of feeds by judicious use of common feedstuffs or by pelleting, but the inclusion of fat is frequently a simpler method of attaining this objective. Consequently, moderately priced fats are of extreme interest to progressive manufacturers of feeds.

In view of the many advantages of including fat in feeds, it would seem that this material would be a rather valuable feedstuff. But how valuable is it? It is difficult to assess an increase in the value of a feed resulting from improvements of color, texture, or palatability or from reduction of dustiness. We know that purchasers prefer "bright, clean feeds"; but we also know that they are very price-conscious and will not knowingly pay large premiums for non-essentials if competitive feeds offer comparable nutritive value and palatability at a lower price. Hence it is to nutritive value that we must look for most of the value in fats. The actual economic value of fat nutritionally may be calculated in two ways:

a) From analyses of fats and other energy feedstuffs, and
b) From the results of animal experimentation.

Since fats primarily provide energy, they must compete pricewise with the cheapest non-fat source of energy. Ordinarily this is corn. By calculation, good quality No. 1 or No. 2 corn contains 3.5 calories per gram, and fats such as tallow contain 9 calories per gram. Thus fats are approximately 2½ times as rich in calories as corn and on that basis have a minimum value of at least 2½ times the cost of corn. Corn pro-

[1] Presented at the 27th annual fall meeting, American Oil Chemists' Society, Chicago, Ill., Nov. 2-4, 1953.

TABLE I

Type and No. Animals Fed Each Ration [a]	Level and Type of Fat Added to Experimental Diets [b] %	Feed Required Per Pound Gain		Retail Value of Feed		Value of Fat Used	
		Control Pounds	Exptl. Pounds	Control $/cwt.	Exptl. $/cwt.	Total (cents)	Per Pound (cents)
Broilers —1100	3 S	2.84	2.70	5.35	5.63	37	12.3
Broilers —1100	3 T	2.84	2.68	5.35	5.66	40	13.3
Broilers —1100	3 C	2.84	2.87	5.35	5.29	3	1.0
Broilers —1125	3 T	3.08	3.00	5.35	5.49	23	7.7
Broilers —1100	3 S	2.81	2.78	5.35	5.41	15	5.0
Broilers —1100	5 S	2.81	2.74	5.35	5.48	22	7.3
Broilers — 20	5 T	3.08	2.84	5.35	5.80	60	12.0
Broilers — 20	5 S	3.08	2.98	5.35	5.53	33	6.6
Broilers — 20	5 C	3.08	2.94	5.35	5.60	40	8.0
Broilers — 20	5 T	3.08	2.94	5.35	5.80	60	12.0
Broilers — 20	7 S	3.08	2.77	5.35	5.95	81	11.6
Broilers — 20	14 S	3.08	2.86	5.35	5.76	83	5.9
Broilers — 20	14 S [c]	3.08	2.77	5.35	5.95	64 [c]	4.6
Ducks — 20	5 T	4.03	3.82	4.45	4.70	40	8.0
Ducks — 20	5 T	4.09	4.04	4.45	4.51	21	4.2
Ducks — 20	5 S	4.38	3.89	4.45	5.02	72	14.4
Ducks — 20	5 C	4.38	3.81	4.45	5.11	83	16.6
Turkeys — 30	5 T [d]	5.43	4.86	4.75	5.31	71	14.2
Swine — 10	5 T	3.96	3.69	3.88	4.16	43	8.6
Swine — 10	3 C	3.42	3.26	3.54	3.72	33	6.6
Swine — 10	3 S	3.42	3.46	3.54	3.50	11	2.2
Swine — 10	3 T	3.42	3.27	3.54	3.70	31	6.2
Data from the Literature							
Chickens— 150	(1) 2 T	2.60	2.53	4.35	4.47	18	9.0
Chickens— 150	4 T	2.60	2.45	4.35	4.61	38	9.5
Chickens— 150	8 T	2.60	2.44	4.35	4.64	53	6.6
Pigs — 24	(2a) 3.1 M	3.82	3.76	4.02	4.09 (2c)	14	4.5
Pigs — 24	(2a) 6.2 M	3.82	3.40	4.02	4.52 (2c)	65	10.5
Pigs — 24	(2b) 3.1 M	3.92	3.65	4.02	4.32 (2c)	37	11.9
Pigs — 24	(2b) 6.2 M	3.92	3.27	4.02	4.82 (2c)	95	15.3
Pigs — 24	(2a) 3.1 CN	4.05	3.67	3.95	4.38 (2c)	51	16.4
Pigs — 24	(2a) 6.2 CN	4.05	3.34	3.95	4.78 (2c)	105	17.0
Steers — 10	(3) 3.4 T	......	......	......	......	....	12.5
Steers — 4	(4) 4.8 C	8.24	7.10	2.63	3.05	88	18.3
Steers — 4	(4) 4.9 C	8.22	7.33	2.56	2.87	64	13.1

[a] Only approximate as control and experimental groups sometimes varied in numbers due to mortality or uneven initial distributions. The numbers are given only as an indication of the sizes of the test groups.
[b] Source of fat indicated by symbols as follows: T—tallows & greases; C—hydrolyzed cottonseed fats (foots); M—corn oil; CN—coconut oil; S—hydrolyzed soybean fats (foots).
[c] The experimental feed contained sufficiently more protein, vitamins, and minerals to make the ratios of these nutrients to calories the same as the corresponding ratios in the control feed.
[d] Fattening period only.
1. Effect of Feeding Graded Levels of Fat With and Without Choline and Antibiotic B_{12} Supplements to Chicks, A. J. Siedler and B. S. Schweigert, Poultry Science, *32*, 449-54 (1953).
2a. W. L. Robison, "Fat in Rations for Swine," Bimonthly Bulletins, Vol. XXVIII, No. 224, September and October, 1943.
2b. *Ibid.*, Pigs Limited Slightly as Compared to Full Feeding in 2a.
2c. Rations fed the Experimental Lots Varied Slightly from the Control.
3. J. Matsushima and T. W. Dowe, Nebraska Cattle Reports 219, 1953.
4. Willey, Riggs, Colby, Butler, and Reiser, J. Animal Science, *11*, 705-11 (1952).

vides some protein, vitamins, and minerals, but the amounts of these are not appreciable at the levels at which fat may be used most advantageously. Thus, with corn selling at 3 cents per pound, the minimum energy value of fat must be 7½ cents per pound. However fats are 90-95% digested and absorbed whereas corn is 80% utilized, based upon Morrison's tables. When digestibility is considered, the energy value of fat, relative to corn, increases to over 8 cents per pound.

This calculated value may be considered as a minimum. There are many indications that fats contribute to the efficiency of utilization of other nutrients in certain rations. Improvements in palatability or reductions of wastage during feeding likewise contribute to economy in production. It is difficult to estimate how significantly these factors may affect the value of a feed under practical conditions, but in closely controlled experiments the value of fat under laboratory conditions of feeding can be determined. This has been done for a number of our experiments and for some published data according to the following outline:

A. The ingredient cost of the control ration has been calculated.
B. From experimental data for animals fed the control rations, the amount of feed required per pound of gain has been determined.
C. Also from the data the amount of experimental feed required per pound of gain has been determined. This amount of feed has a value equivalent to the cost of the control ration needed to produce a pound of gain, as calculated in B. From these two figures and the cost of the control ration the value of experimental feed per pound can be obtained.
D. Using this value for the mixed experimental feed and the same ingredient prices as in (A), the value of the fat can be determined as the difference between the cost of the regular ingredients and the experimental value.

As an example, in a broiler feeding experiment the control ration, a 21% protein complete broiler mash with a retail cost estimated at $5.35 per hundred pounds, was compared with a feed identical in composition except that 3% of the corn was replaced with 3% of fat. Chicks on the control ration required 2.84 pounds of feed per pound of gain. Those on the experimental ration however required less feed, using 2.70 pounds per pound of gain. The value of the experimental feed then becomes $5.35 \times 2.84/2.70$, or 5.63 per cwt. Ingredients other than fat cost $5.26 for 97 pounds.[2] Thus the 3 pounds of fat making up the remaining 3% of the feed had a value of $5.63 — 5.26, or $0.37. Table I shows the basic data for this calculation and similar data for a number of other experiments in our laboratory, using estimated current retail prices for the control feeds. It is believed that these most nearly reflect the true value of fat since improvements in feed efficiency result in lowered mixing, bagging, transportation, and overhead costs as well as lowered feed cost when the amount of feed required to produce a pound of gain is considered.

It should be noted that the levels of fat are 5% or above in many of the comparisons. These higher levels were used in order to obtain more definite data regarding the values of fat. At lower levels differences between groups might have been so slight that interpretations would have been impossible because of experimental variations. As it was, in all cases except two, the addition of fat to feed resulted in improved feed efficiency. The differences in feed efficiencies were so small however that repeated tests were made in order to confirm the observations.

Using these relatively high levels of fat, we hoped also to detect possible detrimental effects which might not be evident with low levels of fat. In this respect attention is directed to the lines in Table I, where data are reported for an experiment in which 7 and 14% fat were fed to broilers. This fat consisted mainly of fatty acids from cottonseed oil foots. Despite this high level of fatty acids the broilers thrived, grew more rapidly than the controls, and used their feed more efficiently. Such a high level of fat increases caloric content of the feed so greatly that deficiencies of other nutrients may occur. In a companion test the same level of fatty acids was fed in a ration in which proteins, vitamins, and minerals had been adjusted to maintain the caloric-nutrient ratios equal to those of the control feed. Growth and feed efficiency were improved although in neither case did inclusion of fatty acids in the feed at such high levels prove to be as valuable as when used at the 7% level.

Even with the high levels of fat, some of which were of low grade (*e.g.*, brown grease), there were no gross indications that carcass quality or composition was altered although use of 5% or more of hydrolyzed cottonseed foots intensified the yellow color of the surface fat. Taste panels have not detected any difference in flavor between experimental and control samples of broilers, ducks, and turkeys—species which tend to transfer undesirable flavors from feed to their flesh. Likewise the thickness of the back fat of swine is no greater than that for controls. Flavor and physical properties of fat rendered from the fatty tissues likewise were similar.

These values in Table I represent actual return to the feeder. They do not include intangibles such as improved color and texture or decrease in dustiness, which may contribute appreciably to ease of selling. It should be noted that in certain cases there is no evidence that fat improves the feed. This may be due to the experimental conditions used, to variations in animals selected for test, to the quality of the fat, etc. Whatever the reason, these more moderate returns serve as a warning that feeders cannot always pay high prices for fat. The effectiveness of the fat depends upon the quality of the feed to which it is added. When added to feeds supplying limited amounts of essential nutrients, it may even induce deficiencies due to the need for fewer pounds of feed to supply calories. A number of different fats have been used in the experiments reported, but for the purpose of this discussion they have been considered only as fat since the nutritive values of animal and vegetable fats of various origins are similar.

Furthermore the calculations used do not take into account any extra expenses that may be incurred in manufacturing feeds containing fat. Naturally such expenses must be borne by that ingredient. Insofar as the feeder is concerned, the values shown in Table I are maximal and must include all costs for ingredients, storage, manufacturing, extra advertising, overhead, profits, etc. Even with these provisions there appears to be ample feed value in fats to encourage their widespread use in mixed feeds so long as their prices do not increase markedly over those prevailing currently for products suitable for use in feeds.

While there are benefits from the use of fat in feeds, there are also factors which deter its use. One of these is lack of familiarity with the properties of fats. They are new ingredients for most feed manufacturers, and new equipment may be needed. Larger mills, especially, must have holding tanks, heating coils, pumps, piping, spray nozzles, and control apparatus. Small mixers may be able to store their supplies in drums and to make additions by hand. This will minimize storage and machinery investments, but purchase prices will be higher and more labor is involved. On the other hand, there are advantages to the manufacture of feeds containing fats. As little as 1% fat in feeds tends to coat and protect mixers and conveying equipment and to facilitate pelleting. In one case where accurate records were kept, the rate of production of pellets was quadrupled following the addition of 1% of fat to the mixture. These advantages, plus the decrease in dust, may well offset the more apparent costs.

When melted, fats offer no special problem in mixing with most feeds. Frequently they can be poured into the mixer from a pail or a sprinkling can and will be thoroughly and evenly distributed during regular mixing time. Five-gallon pails with holes punched through the bottom have been successfully used by small-volume mixers. The addition of fat to finely ground feeds usually necessitates the use of sprayers or sprinklers to prevent formation of small lumps. In general, the manufacturing problems are similar to those involved in the use of molasses or other liquids.

Another point of concern to feed manufacturers is price. The feed business is very competitive, and an increase in the price of feed, even with an improvement in quality, results in competitive disadvantage. Fats which are more expensive than corn will of necessity increase cost unless other changes are made in the formula. The extent of these increases may be seen in Table II. It is very obvious that the feed dealer attempting to sell a feed containing 3% of a 10 cents per pound fat will encounter considerable sales resistance when he increases his price by $4.20 per ton or more depending upon increased manufac-

[2] $5.35 — 0.09 (cost of 3 lb. corn @ 3¢) = $5.26.

TABLE II
Increase In Ingredient Cost of Mixed Feeds When Fat Is Included

Price of Fat per pound	Increase in Ingredient Cost in Dollars per Ton for Various Levels of Fat					
	1%	2%	3%	4%	5%	10%
3¢	0	0	0	0	0	0
4¢	$0.20	$0.40	$0.60	$0.80	$1.00	$ 2.00
5¢	0.40	0.80	1.20	1.60	2.00	4.00
6¢	0.60	1.20	1.80	2.40	3.00	6.00
7¢	0.80	1.60	2.40	3.20	4.00	8.00
8¢	1.00	2.00	3.00	4.00	5.00	10.00
9¢	1.20	2.40	3.60	4.80	6.00	12.00
10¢	1.40	2.80	4.20	5.60	7.00	14.00

turing cost. Feeders however are reasonable people and are willing to pay higher prices for better quality feeds. Upon proof of quality by feeding in their own feedlots, resales may be expected. Data of the type presented above plus the improvements in physical characteristics should suffice to introduce fats into our mixed feeds on a wide scale. Whether it will become a permanently popular feedstuff remains to be seen. Much may depend upon cooperation between the fat and feed industries and upon prices which are in line with the nutritive value of the fats. Under favorable circumstances the potential use of fat is enormous. If we accept estimates of the total volume of commercial mixed feeds in this country of 35 million tons, a 1% enrichment of all feeds with fat would utilize 700,000,000 pounds of fat. At 3%, an amount which most feeds will carry without becoming at all greasy, over 2 billion pounds could be used. When this is compared with the estimated production of inedible tallows and grease for 1951, 2.25 billion pounds, the possible significance of current trends may be appreciated.

Summary

Fats are nutritious; they improve physical characteristics of feeds, and they have shown their value when used in practical tests. They present manufacturing problems, but they also sometimes contribute to the ease and efficiency of feed mixing. If their prices remain within the range which the feed industry can afford, fats should become common feedstuffs and should be used in large volume.

The Aliphatic Woolwax Alcohols. A Review

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WOOLWAX is a mixture of esters of higher fatty acids with higher alcohols. The alcohols may be divided into three classes: sterols, triterpene alcohols, and aliphatic alcohols. Although much is now known about the composition and structure of the fatty acids, sterols, and "triterpene alcohols,"[1] this is not the case with the aliphatic alcohols, which have not had the same extensive study which Weitkamp (24) has made of the fatty acids.

Recently investigations with urea adduct have been published by Truter (28) and von Rudloff (29); Horn and Hougen (30) have had results with chromatography whereas Murray and Schoenfeld (35) are engaged in analysis by low pressure fractional distillation. The results of these modern analyses are very remarkable and will be discussed later.

Moreover it is obvious that in several reviews in recent years the facts, available from literature, have not always been critically summarized. In some cases even corrections of wrong results or wrong conclusions published long ago have been overlooked! It is the purpose of this article to draw attention to this situation and to remove some of the misunderstandings. As each alcohol is considered, the validity of the available information will be critically examined. They will be dealt with in sequence of increasing molecular weight.

n-Octanol. $C_8H_{17}OH$. In 1887 Guetta (3) announced that he had isolated octyl alcohol from the products of distillation of woolwax. Hannau (4) could not confirm this alcohol in distilled woolwax. Lewkowitsch (5) imputed this to the fact that higher alcohols form hydrocarbons when distilled, but he failed to state that this also holds for octyl alcohol. As this alcohol is not mentioned by other investigators, it can be ignored.

Decenol. $C_{10}H_{19}OH$. In 1895 Darmstädter and Lifschütz (7) announced the isolation of an unsaturated alcohol $C_{10}H_{19}OH$. After a year they recalled this communication however (8) as on further investigation the compound proved to be not an alcohol, but lanocerinacidanhydrid. This alcohol has not been mentioned by other investigators so that it was incorrectly included in some recent reviews (22, 23, 26).

Hendecenol. $C_{11}H_{21}OH$, too, was discovered by Darmstädter and Lifschütz (7), who thought it to be the second alcohol in a series of which decenol should be the first and lanolinalcohol the third homologue. After a year however they announced that they doubted the existence of this alcohol, and further information was promised (8) but never published. So this alcohol also, not being mentioned in other publications, was incorrectly included by Warth (26) and Lower (22, 23).

Dodecenol. $C_{12}H_{23}OH$. Lower (22, 23) is also the only reviewer who refers to an unsaturated alcohol with 12 C-atoms besides lanolinalcohol. However no source of information is given so that this compound can be ignored.

Lanolinalcohol. $C_{12}H_{23}OH$. There is much confusion in literature about this alcohol. In 1895 Marchetti (6) announced the isolation from woolwax of an unsaturated alcohol with 12 C-atoms, which he called lanolinalcohol. It did not absorb bromine however and formed 1% of the woolwax (and not 0.1% as Röhmann (12) incorrectly recorded). In 1916 Röhmann (12) described lanocerinacidanhydrid, a substance isolated from carnauba wax by Stürcke (2) in 1884 and from woolwax by Darmstädter and Lifschütz (8) in 1895, and mentions that Lifschütz had told him that lanocerinacidanhydrid was identical

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[1] Ruzicka *et al.* (37, 39) and Curtis c.s. (38) recently demonstrated that the "triterpene woolwax alcohols" have not the structure of triterpene alcohols but the cyclopentanoperhydrophenanthrene skeleton of the sterols, the side chain attached at the same point! The three extra methyl groups however appear to be located like those in the triterpenes.