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Director's Digest

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# THE VALUE OF FAT IN POULTRY FEEDS:

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## I. General Considerations

### INTRODUCTION

The phenomenal growth of the poultry industry in the last 50 years can be attributed largely to the increasingly economical production of poultry and eggs. The price of chicken to the consumer has remained almost constant during this period, in contrast to the inflationary costs of most other goods and services. A major factor in this remarkable production efficiency was the discovery of the value of fat in poultry feeds. Without added fat we could not achieve the high energy rations so universally used and which are absolutely essential if poultry is to maintain its competitive economic advantage over other foods.

We tend to think of fat simply as a concentrated source of energy, which it is, but there are other valid reasons for using fat perhaps equally important. These include the improvement in physical characteristics of the feed when fat is added and its contribution of the essential fatty acid - linoleic acid (Fuller, 1986).

### Physical Improvement of Feed

The first increment of supplemental fat will improve the physical characteristics of the feeds sufficiently to justify its use at almost any price. These improvements include:

1. Its lubricating value
2. Reduction of dust
3. Reduction of particle separation
4. Palatability

Lubrication value - Feed is very abrasive and will cause excessive wear on mixing and milling equipment as well as feed handling equipment in the chicken house. A small amount of added fat reduces the abrasiveness of the feed, thereby increasing the life of the feed mixing and handling equipment. Similarly, the power requirement for pelleting feeds has been shown to be reduced markedly by adding even 1 or 2% of fat to the feed and several fold increases in the life of the pelleting dies has been demonstrated.

Reduction of dust - Feed is dusty. Losses due to dust at the grinding, mixing, conveying and handling operations have been estimated to be as much as 2% when supplemental fat is not used. Just as important is the impairment of health of the workers in the feed mill and around the poultry operation as a result of respiratory problems due simply to excessive dust. These problems led to a high degree of absenteeism among feed mill employees and the expense of dust collection by mechanical means was a major item of cost in manufacturing feed. With the addition of fat to feed these problems were largely corrected.

Reduction of particle separation - Even the best mixed feed will separate to some extent while being transported long distances and particularly in the poultry house where automatic feeders are used to deliver feed great distances. Studies conducted at the University of Georgia (Charles, 1970) demonstrated great differences in the mineral content of the feed at the beginning and at the end of long feeder chains. This was much worse with layer feeds which contained high levels of limestone. When supplemental fat was used this particle separation was reduced significantly.

Palatability - It is well known that a small amount of supplemental fat will greatly enhance the palatability of feed for all classes of livestock and poultry. (Evidence for this will be discussed later.)

## Essential Fatty Acids

A second reason for adding fat is to provide a supplemental source of linoleic acid (18:2) to help meet the requirement of the chicken for essential fatty acids (EFA). Diets for all classes of poultry which do not rely on corn as the major source of energy are usually borderline or grossly deficient in essential fatty acids (Table 1).

TABLE 1. Linoleic acid (18:2) supplied by grain

| Grain | 18:2 in grain[1]<br>% | X | 60% in ration<br>% |
|---|---|---|---|
| Corn | 1.9 | | 1.14 |
| Barley | 0.5 | | 0.51 |
| Wheat | 0.6 | | 0.36 |
| Sorghum | 0.8-1.1 | | 0.48-0.66 |

[1] Scott et al., 1982.
Requirements: Broilers 1.0%, Layers and Breeders 1.0%.

The use of supplemental fat in such cases is not only desirable but imperative. Most feed grade fats contain enough linoleic acid to fulfill the requirement for additional EFA when used at levels of 2 or 3% in the ration. The value of linoleic acid as a source of EFA should not be confused with its contribution to the energy value of the fat which is similar for all unsaturated fatty acids.

Since the value of fat for its physical attributes is difficult to quantitate, most feed formulators now simply specify a minimum level of about 2% of supplemental fat which takes care of the needed improvement in physical quality of the feed while at the same time providing a margin of safety for the essential fatty acid requirements. These low levels of fat also make a greater than proportional contribution to the energy value of the feed for reasons which will be discussed below.

## Energy Value

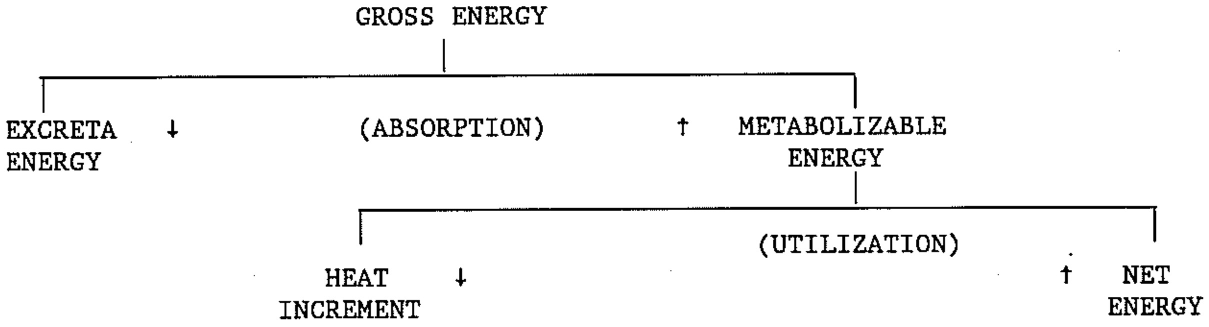
While metabolizable energy (ME) is a satisfactory measure of the energy value of mixed feeds it has serious shortcomings in estimating the effective energy value of individual ingredients such as fat which are used at relatively low levels and which tend to interact with other ration components. It has been well established that ME underestimates the effective energy of fat so that when rations contain supplemental fat performance invariably exceeds predictions based upon empirical values. This phenomenon known as the "Extra Caloric Effect" has been demonstrated in all classes of poultry and laboratory animals (Touchburn and Naber, 1966; Jensen *et al.*, 1970; Sell *et al.*, 1976).

It was at first attributed largely, if not entirely, to the "Associative Dynamic Effect" which was first reported by Forbes and Swift (1944). They observed a reduction in heat increment (or heat loss) when fat was included in the ration mixture. Since that time the metabolizable energy of fat has been shown to be utilized more effectively for growth and fattening than are the ME's of carbohydrates or proteins (De Groote, 1969; Chudy and Schiemann, 1969). This increased efficiency of fat presumably results from the energetically efficient process of converting dietary fatty acids to body fat more or less directly.

It is now well recognized that a large part of the "extra caloric effect" occurs at the absorption level to increase the metabolizable energy of the ration. To distinguish this effect from the "associative dynamic effect" Horani and Sell (1977) proposed the term "Extra Metabolic Effect". Thus the extra caloric effect appears to be the result of two separate phenomena which are additive. At the risk of oversimplification they are: (1) Added fat interacts with other dietary components to increase the absorption of all or part of the ration components which increases the metabolizable energy of the ration as a proportion of the gross energy ("Extra Metabolic Effect"), (2) Added fat increases utilization of the metabolizable energy by reducing the heat increment of the feed which increases the net energy ("Associative Dynamic Effect").

These effects can be seen in Fig. 1. When absorption is improved excreta energy is reduced and ME is increased. When heat increment is reduced utilization is increased and net energy is increased.

Fig. 1. Partition of Food Energy



The extra metabolic effect of fat can, in turn, be attributed to two separate phenomena as follows: (1) Interaction of the supplemental fat and the residual fat in the grain portion of the basal ration to improve the absorption of the more saturated fat. Sibbald *et al.* (1961) demonstrated this interaction (Table 2). Tested individually soybean oil and tallow had ME values of 8.46 and 6.94 kcal/g, respectively, when fed to broiler chicks. When fed together in a 1:1 mixture, the mixed fat was found to contain 8.41 kcal/g. Assuming the soybean oil remained unchanged, the tallow would then have to contain 8.36 kcal/g under these conditions.

TABLE 2. Synergistic effect of different fats
(Sibbald *et al.*, 1961)

| Kind of Fat | Av. ME kcal/g |
|---|---|
| Tallow | 6.94 |
| Cr. Soy Oil | 8.46 |
| Mixed (50:50) | 8.41 |

(2) The ability of supplemental fat to improve the digestion and absorption of the non-lipid portion of the ration. This has been demonstrated by Mateos and Sell (1980) at Iowa State University and by Dr. Reid and associates at the University of Arizona (Reid, 1983). Both researchers, with Fats and Proteins Research Foundation support, have presented convincing evidence that this improvement results from a slowing of the rate of passage of feed through the gastrointestinal tract with consequent increase in digestion and absorption. The effect was greatest when the ration consisted of ingredients that were poorly utilized. A more detailed

discussion of this research will be presented in subsequent sections of this Digest Series dealing with the value of fat in laying rations.

To comprehend the difficulty of assigning a single numerical value to the ME of fat, consider the fact that the ME of a dietary ingredient such as fat is not a direct measurement but is determined by substitution. Thus, it becomes a measure of the effect of the test substance (in this case, fat) on the ME of the test diet. Whatever synergism or interaction that takes place between the test fat and the basal diet is interpreted by extrapolation to be the ME value of the test fat.

Theoretically, the gross energy of the fat multiplied by its absorbability should provide an accurate measure of the metabolizable energy of the fat; however, when this is done, the ME values are invariably found to be considerably lower than when determined by changes in the ME of a test ration according to the traditional method for ME determination. Lewis (1984) at Nottingham, U.K. demonstrated this discrepancy (Table 3).

TABLE 3. Metabolizable energy (kcal/kg) of beef tallow and soybean oil determined by digestibility data or by changes in ration ME's (Lewis, 1984)

| Level fed | Digestibility[1] |  | Changes in ration ME[2] |  |
|---|---|---|---|---|
|  | Tallow | SBO | Tallow | SBO |
| 3 | 7050 | 8720 | 10200 | 10450 |
| 6 | 7180 | 8690 | 8710 | 9650 |
| 9 | 7190 | 8670 | 7200 | 9140 |
| 12 | 6950 | 8610 | 7040 | 8740 |

[1] Digestibility x gross energy.
[2] Conventional ME determination.

## Reducing Heat Stress With Fat

When food is eaten there is an increase in heat production over and above that of the fasting or basal heat production. This is called the heat increment (or dynamic effect) of eating and arises primarily from the chemical reactions involved in converting food energy to the energy needed for maintenance and production. Heat increment (HI) is less when nutrients are fed in combination than when fed separately and the greatest saving in HI occurs when fat is included in the combination (Forbes and Swift, 1944). Thus fat increases the energetic efficiency or ratio of net energy to metabolizable energy of the ration.

When environmental temperatures rise to uncomfortable levels, the heat increment of eating adds to the discomfort of the animal. Pigs and chickens are especially sensitive to high temperatures and consequently reduce their feed intake to avoid the discomfort of the heat increment which must be dissipated. Furthermore, energy must be spent in disposing of this heat through panting, increased peripheral circulation, etc. Thus energy needs are actually increasing while energy is being wasted (as heat increment) and energy intake is decreasing.

The value of dietary fat in alleviating heat stress has been demonstrated with broilers (Dale and Fuller, 1980). This report and supporting data will be described in greater detail in the section dealing with broilers in this Digest Series.

### Increased Energy Consumption Under Conditions Of Stress

One of the major advantages of supplemental fat in rations for both pigs and poultry is the increase in energy intake particularly in times of stress when there is an increased need for energy. Several experiments were conducted at the University of Georgia (Dale and Fuller, 1978) to determine whether broiler chicks would reject high-fat diets during periods of high temperatures. In experiments conducted in controlled environment chambers, and in uninsulated broiler houses, chicks demonstrated a highly significant preference for a high fat diet over similar diets containing a low level of fat. This preference was exhibited at comfortable as well as high temperatures and regardless of the texture of the feed (mash or pellets). The increased intake of feed and energy was observed in the chicks subjected to heat stress in the report cited above (Dale and Fuller, 1978) and was presumed to be a major factor in the alleviation of heat stress.

Reid (1983) observed that fat has its greatest potential in laying hen diets as a concentrated energy source since energy intake above maintenance limits egg production during periods of high environmental temperature. Limited energy intake is also partially responsible for smaller eggs during hot weather. Their studies showed that added animal fat can increase energy intake about 29-30 kcal/day thereby increasing the amount of energy available for production. Young birds tend to deposit this increased energy as increased egg numbers or egg size while older hens tend to deposit the additional energy as body tissue. The report of Jensen (1983) demonstrated this influence of fat on egg weight and rate of production in young pullets during onset of production.

The cause of the increased feed and energy intake is not always clear and may be a combination of factors, for instance:

(1) Concentration of energy in which the same amount of energy is contained in less total feed (or the corollary, when more energy is contained in the same amount of feed). This is important when there is competition among birds, limited feeding time, or condition of stress which tend to limit intake.

(2) Extra caloric effect results in an increase in intake of <u>effective</u> energy although the calculated energy intake remains the same.

(3) Palatability. When birds are given a choice they will invariably select a feed containing added fat over one which does not or even one containing less fat. This is especially important in times of stress.

## SUMMARY

The benefits of adding fat to poultry feeds include non-nutritional as well as nutritional considerations. Among the many benefits are the following (Fuller, 1986):

1. Improves the physical characteristics of the feed. This includes reducing the abrasiveness of feed and in turn prolonging the life of mixing and handling equipment, reducing power requirements for pelleting, reducing dustiness of the feed and problems arising therefrom, and improving its palatability.
2. Provides essential fatty acids.
3. Increases nutrient density.
4. Increases the energy value of the feed over and above the caloric value of the fat itself (extra caloric effect).
5. Increases acceptability of feed to both broilers and laying hens.
6. Reduces heat increment of the feed thereby reducing problems arising from heat stress.
7. Increases early egg weights of pullets. When energy levels are increased feed efficiency and egg production are almost always increased.

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# THE VALUE OF FAT IN POULTRY FEEDS:

## II. Broiler Rations

### INTRODUCTION

Prior to 1950 attempts to utilize supplemental fat in poultry rations had met with little success. Following reports from the Universities of Maryland, Cornell, Connecticut, and others enunciating the principle of the calorie-protein ratio the use of fat became widely accepted. The increased availability of animal fats for livestock and poultry feeds at about this time played a major role in this development.

A minor problem arose with the difficulty of pelleting feeds with the high levels of fat desired. This was soon overcome with the development of spraying fat on the finished pellets which permitted the use of supplemental fat at levels as high as 7 or 8% in broiler rations.

During this time poultry breeders, nutritionists and specialists in all aspects of poultry production and health in academia and industry have joined forces to provide a market broiler that will reach 2 kilos in six weeks on 4 kilos of feed or less for a feed conversion of 2.0 or better. Before the advent of added fat 10-12 weeks were required for the same amount of feed (4 kilos) to produce a broiler weighing little more than 1 kilo with feed conversion of 3.0 or more (Table 1).

The many advantages of using fat that apply to poultry feeds in general have been outlined briefly in the introductory issue of this Digest Series. In this issue attention will be given to research findings pertaining particularly to fat in broiler feeds with special attention to research conducted with support from the Fats and Proteins Research Foundation.

### Energy Value Of Fats For Broilers

Renner and Hill (1961) and Young and Garrett (1963) have shown that long chain saturated fatty acids are poorly absorbed by the young chick. These authors also demonstrated that absorption of these fatty acids was influenced by many factors including: (1) presence and level of unsaturated fatty acids in the ration, (2) degree of hydrolysis of the fatty acids, (3) position of the fatty acid on the glyceride moiety, (4) age of the chick. Garrett and Young (1975) demonstrated that increasing the ratio of unsaturated to saturated fatty acids improved the absorption of palmitic acid and of total fatty acids. This has been substantiated in the recent report of Ketels and De Groote (1988). In all of these works it was shown that synergism between added fats due to blending vegetable oils with animal fats or using basal diets with unsaturated lipid fractions (from the grains in the ration) led to increased utilization of the more saturated fats.

TABLE 1. Improvement in efficiency of broiler production

| Year | Av. body weight | | Feed conv. | Days to market |
|---|---|---|---|---|
| | kg | (lbs) | w/w | |
| 1955 | 1.30 | (2.86) | 3.0 | 70 |
| 1965 | 1.67 | (3.67) | 2.3 | 56 |
| 1975 | 1.85 | (4.07) | 2.1 | 50 |
| 1985 | 2.00 | (4.40) | 2.0 | 48 |
| 1990 | 2.00 | (4.40) | 1.94 | 45 |

(Estimate of U.S. Industry Av.)

This synergism was demonstrated by Sibbald *et al.* (1961) and was discussed in the first issue of this series in connection with the "extra caloric effect" of fat. Most published values for the ME of fats are based on laboratory tests which eliminate as far as possible those factors which influence interaction of the test fat and the basal diet as we have just described. This is done for the sake of precision and repeatability but it also sacrifices applicability of the test results because most of these interactions are present to some degree in practical feeding conditions. For instance, in a corn-soybean meal diet with no added fat the total fat content is approximately 2½ to 3%, much of which is corn oil and therefore highly unsaturated. In practical feed formulas this residual fat would certainly influence the absorbability of any long chain saturated fatty acids in the supplemental fat. This interaction was demonstrated in a report by Sibbald and Kramer (1978) in which the true metabolizable energy (TME) of tallow was much greater when tested on a corn-soy based diet than on a wheat-soy based diet (Table

2). When added to the corn based diet the TME of the tallow was 10,510 kcal/kg which exceeded its gross energy value. The differences in TME of the tallow between the wheat and corn based diets diminished as the level of inclusion of supplemental fat increased, illustrating the importance of the ratio of supplemental fat to basal dietary fat in any such comparison.

TABLE 2. Effect of dietary level and basal diet on TME of beef tallow (kcal/kg)

| Basal diet | Level of dietary inclusion (%) | | |
|---|---|---|---|
| | 5 | 10 | 15 |
| Wheat:soy | 8.46 ± .31[1] | 8.02 ± .14 | 7.90 ± .14 |
| Corn:soy | 10.51 ± .36 | 9.18 ± .21 | 8.09 ± .20 |
| Wheat:soy:meat | 8.40 ± .46 | 7.72 ± .19 | 7.55 ± .21 |
| Wheat:soy:fish | 8.78 ± .40 | 8.18 ± .34 | 7.72 ± .13 |
| Mean | 9.04 | 8.28 | 7.82 |

(Sibbald and Kramer, 1978)

[1] Standard error of means.

This concept was tested in experiments conducted at the University of Georgia designed to evaluate the influence of the residual or basal dietary fat on the TME of test fats differing in physical and chemical properties (Fuller and Dale, 1982) (Table 3). The TME of two samples of blended fats and one sample of tallow was determined using a simplified corn-soy basal diet with all of the fat extracted and with the extracted fat added back in increasing increments. The extracted oil was added back to the basal diet in amounts to provide 0-10% of basal fat and the test fats were added at levels of 5-15% resulting in ratios of basal fat to test fat ranging from 0:15 up to 2:1. The TME of tallow and one of the blends was improved as the ratio of basal to test fat was increased up to 1:1 at which point there were no significant differences in TME among the various fats. Even at the narrower ratio of 1:2 the TME of the tallow was equal to or higher than that of either blend and exceeded its gross energy. A ratio of basal fat to supplemental fat of 1:1 would be more typical of feeding practice in the broiler industry. This should give a favorable unsaturated to saturated fatty acid ratio and should permit maximum absorption of the long chain saturated fatty acids.

TABLE 3. Effect of ratio of basal diet fat to test fat on the TME of test fat

| Basal fat | | Test fat | Basal fat / Test fat | TME of Test Fats | | |
|---|---|---|---|---|---|---|
| Added[1] | Total | | | A (blend) | B (blend) | C (tallow) |
| % | % | % | Ratio | kcal/g | kcal/g | kcal/g |
| - | Nil[2] | 15 | 0-15 | 9.04 | 9.76 | 8.26 |
| - | 3.3[3] | 15 | 1:4.5 | 8.39 | 9.10 | 8.27 |
| 1.7 | 5.0 | 10 | 1:2 | 9.02 | 8.84 | 9.73 |
| 4.2 | 7.5 | 7.5 | 1:1 | 9.79 | 9.31 | 10.02 |
| 6.7 | 10.0 | 5.0 | 2:1 | 9.50 | 9.68 | 9.69 |

(Fuller and Dale, 1982)

[1] Fat extracted from sample of corn and soy (2:1) and added back to the unextracted basal diet.
[2] Basal diet from which fat had been extracted.
[3] Unextracted basal diet.

We have seen that the ME is inversely related to level of inclusion in the test diets. However, the energy value of fats has not been adequately investigated at practical levels (2-5%). When such levels are used in conventional ME assays the multiplication of errors introduces a great deal of variation when extrapolating to 100%. Yet it is at these lower levels that the greatest interaction might be expected between supplemental fats and the other ingredients. At the University of Georgia the true metabolizable energy (TME) of corn oil and a sample of tallow were compared when assayed at a practical dietary level (2.5%) (Dale and Fuller, 1982). The test fats were also assayed at a 15% level of inclusion in a glucose-cornstarch basal diet as would be done in conventional ME determinations (Table 4). There was no significant difference between the TME value of corn oil and that of tallow when assayed at a 2.5% level of inclusion in the practical corn-soybean meal diet. All values were in excess of the gross energy of fats, suggesting an improvement in the absorption of other dietary constituents. On the other hand, when assayed at a 15% level in the purified basal diet, the TME of corn oil was significantly higher than that of the tallow as would be expected from literature values.

One of the principle advantages of fat is its energy density. Fat can be used to increase the density of energy and nutrients in the feed which reduces the total weight and volume of feed that must be mixed, handled and transported. When fat is used in this manner with appropriate energy-nutrient ratios maintained, feed efficiency is usually improved more than proportionally. This was demonstrated in some research conducted at the University of Georgia (Dale and Fuller, 1979) (Table 5). In this work 18 parts of corn starch were replaced with 8 parts of fat plus 10 parts of a non-nutritive filler (Diet B - isocaloric substitution) or with 8 parts of fat only (Diet C - calorie for calorie with no restriction on weight).

TABLE 4. TME of test fats as determined with purified and practical diets (kcal/g)

| | Corn oil | Tallow |
|---|---|---|
| Basal Diet | | |
| Practical[1] | 10.91 ± .39[3] | 10.51 ± .50 |
| Purified[2] | 8.91 ± .18 | 7.79 ± .29 |

(Dale and Fuller, 1982)

[1] Assayed at 2½% in corn-soybean meal basal diet.
[2] Assayed at 15% in glucose-corn starch basal.
[3] Standard error of mean.

Thus the density of diets A and B were similar but in the case of diet C, 90 parts were equal in energy and nutrients to 100 parts of A and B. It would be expected that growth and feed conversion would be the same with diet B as with diet A, whereas a 4% improvement in growth and 3% improvement in feed conversion was observed. This improvement from fat alone at the same energy level as the low fat control can be regarded as an "Extra Caloric Effect" of fat which was discussed in the first paper of this Digest Series.

With diet C growth was expected to be similar to diet A but with a 10% improvement in feed conversion; whereas a 10% increase in growth rate and 15% increase in feed conversion was achieved as a result of substituting fat for carbohydrate with consequent increase in density.

The question logically arises as to what energy values should be used for animal fats in formulating practical poultry rations. Throughout the data just presented most values approached 10,000 kcal/kg or greater. This would be a reasonable starting point when the fat is used at practical levels of 2-5% in the ration. Since it has been demonstrated that the energetic contribution of fat is not constant but varies with level and method of usage, the user is in a better position to develop his own estimate of variation from that value and then use that estimate in his own formulation.

TABLE 5. Effect of fat and diet density on broiler performance

| Ingredients | A<br>High starch | B<br>High fat | C<br>Hi fat<br>Hi density |
|---|---|---|---|
| Constant[1] | 82 | 82 | 82 |
| Corn starch | 18 | - | - |
| Filler | - | 10 | - |
| Fat |  | 8 | 8 |
| Total wt. | 100 | 100 | 90 |
| ME (kcal/kg) | 3190 | 3190 | 3525 |
| Protein (%) | 22 | 22 | 24.3 |
| Calories from fat (%) | 13 | 33 | 33 |
| 4-7 week: |  |  |  |
| Body wt. gain[2], g | 1151 | 1198 (+ 4%) | 1263 (+ 10%) |
| Feed/gain | 2.15 | 2.09 (+ 3% | 1.83 (+ 15%) |

[1] Constant ingredients included 2% added fat in all rations.
[2] 4 week av. body wt. 800 g.

## Effect Of Dietary Fat On Heat Stress

The effect of dietary fat in reducing heat increment and thus increasing the net energy value of feeds was mentioned in the first section of this Digest Series.

Heat increment (HI) is the waste heat, or overhead, resulting from the chemical reactions involved in converting food energy to body tissue. HI is only useful in cold weather when it helps to keep the animal warm. In hot weather when the animal doesn't need this extra heat for warmth it becomes a burden because it must be disposed of. Heat dissipation itself requires extra energy (for panting, increased peripheral circulation, etc.) but the energy in the HI has already been converted to heat so it is not available for the work energy needed by the animal; furthermore, since the source of HI is food energy, the very act of eating increases the HI still further. The resulting discomfort causes the bird to slow down or even stop eating altogether. Thus, while energy requirements are increasing, the birds are eating less and receiving less energy resulting in a deficiency of usable energy.

In experiments conducted at the University of Georgia it has been demonstrated that the effects of heat stress in broilers could be partially overcome by replacing carbohydrate calories with fat calories. In two of these experiments broilers were grown in environmental chambers in which temperatures were cycled diurnally in both hot (23-35°C) and cool (13-23°C) chambers as might occur naturally during hot and cool weather, respectively. Experimental diets varied in the percentage of calories contributed by fat from approximately 14% to 28% and as nearly as possible resembled practical broiler finisher diets (Table 6).

TABLE 6. Experimental diets

| | Lo Fat<br>% | Hi Fat<br>% |
|---|---|---|
| Constant ingredients | 31.75 | 31.75 |
| Corn, ground | 63.00 | 46.75 |
| Corn gluten meal (60) | 3.00 | 5.50 |
| Poultry fat | 2.25 | 8.00 |
| Filler[1] | - | 8.00 |
| | 100.00 | 100.00 |
| Calculated Analysis | | |
| ME (kcal/kg) | 3170 | 3170 |
| Protein (%) | 21.7 | 21.8 |
| % Fat calories | 14.5 | 27.7 |

(Dale and Fuller, 1980)

[1] A mixture of builder's sand and cellulose (Solka Floc) (2:1), approximating the bulk density of the low fat diet.

In both experiments, feed intake, body weight gains and feed conversion were significantly improved by increasing the level of dietary fat and the improvement was appreciably greater in the hot environment (Table 7). In the first experiment, the body weight gain of the chicks in the hot environment fed the high-fat diet was actually greater than that of the chicks in the cool environment fed the low-fat diet. Thus, it was possible to alleviate to a great extent the growth-depressing effect of heat stress by the use of high levels of dietary fat. It was concluded that the beneficial effect of diets containing a higher proportion of fat to nonfat calories can be attributed at least in part to the lower heat increment of such diets.

TABLE 7. Influence of diet composition on broiler performance with temperatures cycled diurnally

| | Exp. 1 (4-7 wks.) | | Exp. 2 (4-6½) wks. | |
|---|---|---|---|---|
| | Lo Fat | Hi Fat | Lo Fat | Hi Fat |
| Feed intake, g | | | | |
| Cool[1] | 2643 | 2778 | 2036 | 1995 |
| Hot[2] | 2236 | 2483 | 1628 | 1683 |
| Wt. gain, g | | | | |
| Cool[1] | 1159 | 1286 (+11%) | 974 | 983 (+1%) |
| Hot[2] | 994 | 1188 (+20%) | 747 | 809 (+8%) |
| Difference | 165 (14%) | 98 (8%) | 227 (23%) | 174 (18%) |
| Feed/gain | | | | |
| Cool[1] | 1.28 | 2.16 | 2.09 | 2.03 |
| Hot[2] | 2.25 | 2.09 | 2.18 | 2.08 |

(Dale and Fuller, 1980)

[1] 13-22 degrees C cycled diurnally.
[2] 23-33 degrees C cycled diurnally.

### Preference Of Chicks For Rations Containing Fat

Several experiments have been conducted at the University of Georgia to determine whether broiler chicks would reject high-fat diets during periods of high temperatures (Dale and Fuller, 1982). In one experiment conducted in controlled environment chambers, chicks maintained in a comfortable environment as well as those subjected to heat stress demonstrated a highly significant preference for the high-fat diet (Table 8).

In two experiments conducted in noninsulated broiler houses in mid-summer a clear-cut preference for the high-fat diet was also demonstrated. When broilers were offered only the high-fat diet or the high-carbohydrate diet, body weights and feed efficiencies were significantly better in the groups receiving the high-fat diets. In another experiment, both the high-fat and the low-fat rations were presented in either mash or pellet form. Regardless of texture, the high-fat diet was again selected over the low-fat diet by a highly significant margin (Table 9).

TABLE 8. Effect of diet and environmental temperature on feed preference

| | Hot | | Cool | |
|---|---|---|---|---|
| | High starch | High fat | High starch | High fat |
| Feed consumed % of total | 43.7 | 56.3 | 35.1 | 64.9 |
| No. pens preferring | 1 | 7 | 0 | 8 |

(Dale and Fuller, UGA 1978)

[1] 14.5% of calories from fat.
[2] 28% of calories from fat.

TABLE 9. Effect of diet and texture on feed preference

| | Pellets | | Mash | |
|---|---|---|---|---|
| | High starch | High fat | High starch | High fat |
| Feed consumed % of total | $39.2^{a}$ | $60.8^{b}$ | $42.8^{a}$ | $57.2^{b}$ |

(Dale and Fuller, UGA, 1978)

## SUMMARY

The use of feed grade fats make it possible to produce broiler rations with increased energy and nutrient density with continuing improvement in production efficiency. This has been a major contribution to the growth of the broiler industry.

Metabolizable energy values for animal fats as listed in most tables of analysis grossly underestimate the effective energy value of these fats. Such values fail to consider the interaction of supplemental fats and the other ration components which tends to increase the energy value of the entire ration. Most of the data presented showed values approaching or exceeding 10,000 kcal/kg for feed grade fats when used at practical levels.

Because of its lower heat increment, it is possible to alleviate the effects of heat stress in broilers by the use of high levels of dietary fat. Broiler chicks exhibited a marked preference for high fat diets over high carbohydrate diets.

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# THE VALUE OF FAT IN POULTRY FEEDS:

## III A. Laying Rations: Effect Of Fat On Egg Size, Rate Of Production And Production Efficiency

### INTRODUCTION

As young pullets come into production they begin laying small eggs which become progressively larger throughout the laying cycle. For commercial layers it usually requires 20-30 weeks after onset of production in a flock before most eggs fall into the profitable "large" category. The energy intake of young pullets at onset of production is frequently too low to sustain the climb to peak production and maximum egg weight while at the same time supporting the normal increase in body weight. This can be more pronounced when the pullets are coming into production during hot weather. Not only is feed (and energy) intake reduced but energy requirements are increased due to the energy required for heat dissipation (see section on Heat Stress).

The importance of essential fatty acid (EFA) in achieving maximum egg size has been known for many years (Shutze *et al.*, 1962; Jensen, 1968). Nevertheless, research reports have continued to report beneficial effects of added fat on egg weight and production even when the diet was presumed to contain adequate linoleic acid. Studies have provided evidence for the advantage of adding fat especially during hot weather (Harms and Waldroup, 1963; Blamberg *et al.*, 1964; de Andrade *et al.*, 1977). The answer may lie beyond either energy or EFA, *per se*. Eggs contain about 10% fat which means 4-5 g of fat must be deposited in the egg daily by hens in 80% production. A corn-soy diet contains about 3% fat or less, so with an average feed intake of 100 g the ration would provide at the most only 3 g fat. The rest of the fat deposited in the egg would have to be synthesized from carbohydrates and/or proteins which are relatively inefficient processes. With added fat, the fatty acids could be used directly in the synthesis of egg lipids via the liver and ovary, an energetically efficient process.

Jensen (1983), at the University of Georgia, conducted a series of experiments to determine the effect of added fat in the diet of young pullets during the first 16 weeks of production. The basal corn-soy diet was considered to be adequate in linoleic acid.

In the first experiment, three different sources of lipids were compared at levels of 4% and 8% in the diets. Poultry oil, corn oil, and tallow were the sources of lipids. Diets containing 4% and 8% poultry oil were also compared on an isocaloric basis with the basal diet by using soybean mill feed to reduce the ME level in the diet with added fat. The pullets were fed the diets from 22-38 weeks of age (Table 1). Rate of egg production tended to be higher for birds fed the diets with supplementary fat when energy levels were allowed to rise along with the added fat (Table 1). Rate of egg production was lower for the diet containing 8% poultry oil and 13% soybean mill feed probably due to the bulkiness of this diet.

TABLE 1. Effect of added fat and energy level on the performance of pullets 22-38 weeks of age (Jensen, 1983)

| Added fat %/source | Dietary ME kcal/kg | Egg prod. % | Egg wt. category (%) Small & medium | Large & extra large |
|---|---|---|---|---|
| 0 | 2870 | 59.8 | 48.7 | 39.4 |
| 4 Poultry oil | 2870 | 59.1 | 37.8 | 60.8 |
| 8 Poultry oil | 2870 | 53.3 | 38.5 | 60.3 |
| 4 Poultry oil | 3012 | 66.6 | 42.7 | 56.0 |
| 4 Corn oil | 3012 | 62.7 | 43.0 | 54.7 |
| 4 Tallow | 3012 | 62.4 | 46.5 | 52.2 |
| 8 Poultry oil | 3155 | 65.4 | 36.1 | 61.8 |
| 8 Corn oil | 3155 | 62.7 | 34.3 | 62.6 |
| 8 Tallow | 3155 | 60.8 | 31.9 | 65.5 |

The production of eggs in the category of large and extra large was considerably greater for birds fed the two levels of poultry oil in diets isocaloric with the basal diet, suggesting that the improvement in egg size was related to the presence of additional fat *per se* rather than to energy concentration. When the energy level was permitted to rise along with the added fat both egg production and egg weight were increased, suggesting that both the level of energy as well as the source of that energy were important for maximum egg weight and rate of production.

In another experiment, levels of 0%, 1%, and 2% feed grade animal fat (FGAF) were compared when added to the diet of pullets 22-38 weeks of age. Rate of egg production was slightly higher for the birds fed the two levels of animal fat with no apparent difference in rate of body weight gain (Table 2). Both the 1% and 2%

levels resulted in a greater proportion of eggs falling in the large and extra-large categories.

TABLE 2. Effects of dietary fat on performance of pullets from 22-38 weeks of age (Jensen, 1983)

| Added fat %/source | Egg prod. % | Body wt. gain g | Egg wt. category (%) | |
|---|---|---|---|---|
| | | | Small & medium | Large & extra large |
| 0 | 66.4 | 362 | 53.1 | 46.3 |
| 1 FGAF[1] | 69.3 | 334 | 45.0 | 54.2 |
| 2 FGAF | 70.0 | 358 | 46.8 | 52.5 |

[1] Feed grade animal fat.

Results of these experiments show that supplementary fat during the first 16 weeks of egg production generally results in an accelerated increase in egg weight. As little as 1% or 2% added fat improved egg size in the studies and there was also a tendency for rate of egg production to be somewhat higher with diets containing added fat.

Sell *et al.* (1987) studied the influence of dietary fat on weight of eggs and yolks during early egg production. Beginning at 24 weeks of age White Leghorn pullets were fed corn-soy diets containing 0, 3, or 6% A-V fat added with or without increasing energy levels. There were no significant effects of fat on ME consumption during the experiment (24-38 weeks of age) nor on rate of egg production.

No diet effects on egg or yolk weights were observed during the early weeks of the experiment but by 28 weeks of age yolk weight was observed to increase linearly with level of fat (P<.01). Effect of fat on egg weights was less than the effect on yolk since the weight of egg whites was not affected. The greatest effect of supplemental fat on yolk weight occurred when hens were 30-34 weeks of age. Their results demonstrated that supplemental fat increased egg and yolk weights even though the average consumption of ME by hens was essentially the same across all diets.

Furthermore, the results demonstrated that improvements in egg and yolk weights caused by supplemental fat occurred even though the diet without added fat was adequate in linoleic acid as recommended by the NRC (1984). This supports the contention of Whitehead (1981) and Jensen (1983).

Dr. Reid (1983) at the University of Arizona has conducted a number of experiments to measure the effects of tallow on energy utilization in laying hens. In one study, the addition of 3% tallow to a laying hen diet increased egg output (weight/time) by 10.4%, increased ME intake 4.1% and energy retention by 9.8% (Table 3). These improvements were fairly consistent in a number of short-term studies.

TABLE 3. Effect of tallow on energy utilization in laying hens (Reid, 1983)

| Criteria | Added tallow, % |  | % Change |
|---|---|---|---|
|  | 0 | 3 |  |
| Egg output, g/day | 48.2[a] | 53.2[b] | 10.4 |
| ME intake, kcal/day | 291 | 303 | 4.1 |
| BW change, g/day | 2.0 | 2.1 | ---- |
| ME above maintenance, kcal/d | 131 | 143 | 9.2 |
| Energy balance, kcal/d | 87.1 | 95.6 | 9.8 |
| Energetic efficiency, % | 66.5 | 66.9 | 1.0 |

[a,b] Means within a row not having common letter superscripts are significantly different ($P<.05$).

In an extensive study, 3% and 6% yellow grease (YG) were fed for 12 28-day periods to laying hens in cages. Egg production rate was increased from 78.1% on the basal diet to 84.1% with 3% YG and to 80.7% with the 6% level. Feed conversion was significantly improved by each of the supplements and amounted to a saving of 35 g feed for each 1% YG added to the feed. This resulted in a 6.7% saving in feed/dozen eggs at the 3% level and 11.8% at the 6% level of added fat (Table 4).

In a similar study, dietary protein levels of 14%, 16%, and 18% and a diet formulated to NRC amino acid recommendations were fed for nine 28-day periods with and without 4% added tallow. Increases in egg production were obtained in all treatments receiving tallow although the differences were statistically significant only with the 14% protein and the amino acid restricted diets. Feed conversion was significantly improved for all groups receiving tallow.

TABLE 4. Yellow grease and laying hen performance (Reid, 1983)

| Dietary treatment | Egg production (%) | Feed conversion (kg/doz) | ME intake (kcal/day) |
|---|---|---|---|
| Basal diet | 78.1[a] | 1.78[a] | 314[a] |
| 3% Yellow grease | 84.1[b] | 1.66[b] | 332[b] |
| 6% Yellow grease | 80.7[ab] | 1.57[c] | 313[a] |

[a-c]Means within a column not having common letter superscripts are significantly different ($P<.05$).

Summarizing the data over dietary protein levels show that the average improvement due to tallow was 5.7% in rate of egg production and 8.4% in feed conversion (Table 5). Feed intake was not significantly reduced in the tallow-fed groups, resulting in an increase in ME intake averaging 32 kcal/day and a 5.6% increase in egg output (g/day). The apparent metabolizable energy (AME) of tallow in this study was determined to be 9.85 kcal/g which exceeds its gross energy.

Increases in ME intake with the feeding of tallow at levels from 1% - 4% were a consistent finding in the studies at Arizona (Reid, 1983). In five experiments conducted at constant temperatures of 13° to 35°C (55° to 95°F) the average increase in ME intakes above maintenance with 3% dietary tallow was 32 kcal/bird/day with a standard deviation of 7 kcal.

TABLE 5. Summary of tallow effects (Reid, 1983)

| Tallow (%) | Egg prod. (%) | Feed conv. (kg/doz) | Feed intake (g/day) | ME intake (kcal) | Egg output (g/day) |
|---|---|---|---|---|---|
| 0 | 73.3[a] | 1.91[a] | 112[a] | 299 | 46.3 |
| 4.0 | 77.5[b] | 1.75[b] | 110[a] | 331 | 48.9 |

[a,b]Means within a column not having common letter superscripts are significantly different ($P<.05$).

With an expected energetic efficiency for production of 70%-75% (Valencia *et al.*, 1980) this would allow 22 to 23 kcal of energy for increased egg output or body weight gain. According to Reid (1983), younger birds tended to increase egg output rather than body weight; whereas, older birds tended to increase in body weight. They found tallow to be particularly useful during periods of temperature stress, either hot or cold, when ME intakes above maintenance requirements decrease, thus limiting production. It was concluded by the author that this stimulation of energy intake is one of the special effects which can be beneficial in improving productivity in laying hens.

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## III B. Laying Rations: Extra Caloric Effect Of Fat In Laying Rations

### INTRODUCTION

In the 1970s while still at North Dakota State University, Dr. Sell and his colleagues undertook an extensive research program with FPRF support to determine whether dietary fat exerted an "extra-caloric" influence on productive efficiency of laying hens. The effect of the grain component of the ration on the hen's response to added fat was also studied (Sell, 1977).

One experiment was conducted to compare the efficacy of two levels of feed grade animal fat (FGAF) (2.5% and 5%) with the same levels of soybean oil. The basal rations were wheat-soy and the ME:protein ratios were kept similar. Fat supplementation increased the rate of egg production and markedly increased efficiency of feed utilization. FGAF was equal to soybean oil in this respect (Table 1). Average egg weight was also improved by the added fat. The efficiency in feed utilization exceeded expectations based upon calculated values. The author pointed out that these were wheat-based rations which may have been deficient or borderline in linoleic acid which would have accounted for a part of the beneficial effect of added fat.

TABLE 1. Effect of level and source of fat on laying hen performance (Sell, 1977)

| Added fat source/% | Hen-day production % | Feed per doz. eggs kg | Av. egg weight g |
|---|---|---|---|
| None | 71.2[a] | 2.02[a] | 60.7[a] |
| FGAF 2.5 | 76.2[b] | 1.84[b] | 60.9[a] |
| FGAF 5.0 | 75.3[b] | 1.76[b] | 62.0[b] |
| Soy oil 2.5 | 76.3[b] | 1.82[b] | 63.1[b] |
| Soy oil 5.0 | 75.2[b] | 1.79[b] | 62.1[b] |

[a] Each ration fed to 5 replicates of 16 hens each (252 days).
[b] Means in the same column followed by same superscript letter are not significantly different.

In a second experiment, corn, wheat, oats, barley, and millet were compared with and without added fat. The level of fat added with each grain varied but resulted in ME concentrations comparable to those used in practical situations.

The calorie-protein ratios within each grain series were similar for the fat and no-fat rations. Each ration was fed to 4 reps of 16 hens each for 260 days. The results (Table 2) show that the addition of fat markedly improved the rates and efficiency of egg production. Again, the magnitude of improvement in feed utilization exceeded expectations. The reason for this may be explained by the data shown in Table 3 which demonstrates the extra metabolic effect of the added fat. Note that the measured ME's exceed the calculated ME values in all cases.

TABLE 2. Effect of type of grain and supplemental fat[1]
on egg production and feed conversion - Exp. 2
(Sell, 1977)

| | Egg production (%) | | Feed conversion | |
|---|---|---|---|---|
| Grain | No fat | Added fat | No fat | Added fat |
| Corn | $75.6^{abc}$ | $80.1^{a}$ | $1.80^{d}$ | $1.67^{e}$ |
| Wheat | $74.5^{bc}$ | $76.7^{abc}$ | $1.83^{cd}$ | $1.75^{de}$ |
| Oats | $58.9^{c}$ | $71.7^{cd}$ | $2.49^{a}$ | $1.97^{c}$ |
| Barley | $66.5^{d}$ | $76.0^{abc}$ | $2.20^{b}$ | $1.86^{c}$ |
| Millet | $73.8^{bcd}$ | $78.6^{ab}$ | $1.95^{c}$ | $1.72^{de}$ |

[1] Levels of fat added were as follows: corn 2%, wheat 3%, oats 5%, barley 5%, millet 5%.

In subsequent trials, Horani and Sell (1977) demonstrated that the addition of 2% or 4% fat to laying hen rations based on corn, oats, barley, or combinations of these grains significantly ($P<.05$) decreased feed consumption and improved feed efficiency.

Added fat was found to have an "extra metabolic effect" whereby the change in ration ME's caused by fat as measured experimentally exceeded that anticipated on the basis of calculated ME of the ration. This effect was mainly observed in rations with 4% added fat and in rations where corn was one of the ingredients. The apparent ME of fat, therefore, would approach or exceed its gross energy value if this "extra metabolic effect" was entirely attributed to added fat (see Table 4).

TABLE 3. Metabolizable energy values of rations as influenced by dietary fat - Exp. 2 (Sell, 1977)

| Ration treatment | Calculated basis | | As measured | |
|---|---|---|---|---|
| | Ration M.E. | Change due to fat | Ration M.E. | Change due to fat |
| | (kcal/kg dry matter) | | | |
| No added fat | | | | |
| Corn | 3005 | --- | 2990 ± 83[1] | --- |
| Wheat | 2895 | --- | 2815 ± 36 | --- |
| Oats | 2430 | --- | 2475 ± 38 | --- |
| Barley | 2520 | --- | 2485 ± 29 | --- |
| Millet | 2605 | --- | 2680 ± 96 | --- |
| Added fat | | | | |
| Corn + 2% | 3075 | 70[2] | 3110 ± 37 | 120[2] |
| Wheat + 3% | 3015 | 120 | 3095 ± 69 | 280 |
| Oats + 5% | 2680 | 250 | 2865 ± 59 | 390 |
| Barley + 5% | 2765 | 245 | 2895 ± 44 | 410 |
| Millet + 5% | 2835 | 230 | 3090 ± 24 | 410 |

[1] Means ± standard errors.

[2] All changes are in relation to the ration with no added fat for each respective grain.

TABLE 4. Apparent ME of tallow based on changes in ration ME's attributable to fat supplements in diets of laying hens - Exp. 3 (Sell, 1977)

| Grain component | Apparent ME |
|---|---|
| | (kcal/kg) |
| Corn | 10,300 |
| Oats | 10,375 |
| Barley | 9,250 |

They suggested the term "Extra Metabolic Effect" to distinguish it from the "Extra Caloric Effect" described by Carew and Hill (1964), Touchburn and Naber (1966), and Jensen *et al*. (1970). The extra caloric effect described by the earlier workers was attributable, at least in part, to the improvement in efficiency with which the ME was utilized as a consequence of reduced heat increment and would thus apply to an increase in net energy as a proportion of the ME. The term "Extra Metabolic Effect" was applied to the increase in ME resulting from increased absorption of the entire diet including the fat.

A number of studies with chicks had demonstrated an increase in the absorption, and therefore of the ME, of the more saturated animal fats resulting from interaction with the relatively unsaturated fats residual in the grain portion of the basal diet. Mateos and Sell (1980a) determined the ME and TME of yellow grease when included at several levels in corn-based diets. The extra metabolic effect of yellow grease was greatest at low levels of fat inclusion and diminished in a linear manner as level of added fat increased. The authors concluded that the interactions among the fatty acids of dietary fats can contribute to the extra metabolic effect but the potential manifestation of this interaction does not fully explain the total extra metabolic responses when ME values appear to exceed their gross energies. They concluded that it was logical to assume that supplemental fats must be causing changes to occur in the utilization of energy from non-lipid dietary constituents.

A series of experiments were conducted at Iowa State University (Mateos & Sell, 1980b,c) to determine the extent of interactions between supplemental fat and various carbohydrates with respect to energy utilization by laying hens. The results demonstrated two significant phenomena. In agreement with their earlier work, supplemental yellow grease increased the ME of diets containing corn starch, sucrose, or rice hulls more than would be expected, thereby illustrating the extra metabolic effect of added fat. In addition, the data suggested a significant fat x carbohydrate interaction. As shown in Table 5, the ME of yellow grease was nearly 8,900 kcal/kg on the basis of the data obtained from test diets containing 20% sucrose but only 8,200 to 8,250 kcal of ME/kg when tested in starch or rice hull diets.

An experiment was conducted using starch or sucrose at 47% of the diet (Mateos & Sell, 1980c). Yellow grease was tested at 0% and 7% in these diets. The dietary ME values determined experimentally were used to estimate the ME of yellow grease. The ME's of yellow grease were 9,714 and 10,071 kcal/kg for the starch-based and sucrose-based diets, respectively (Table 6).

TABLE 5. Estimated ME of yellow grease as determined with diets containing starch, sucrose or rice hulls (Mateos & Sell, 1980b)

| Dietary carbohydrates[1] | ME of yellow grease (kcal/kg)[2] |
|---|---|
| Starch | 8,247 |
| Sucrose | 8,897 |
| Rice hulls | 8,221 |

[1] Constituted 20% of the diet.

[2] Estimated on the basis of regression analysis of dietary ME's obtained with supplemental yellow grease levels of 0%, 4%, 8%, and 12%.

TABLE 6. Influence of carbohydrate source and method of estimation on ME of yellow grease (Mateos & Sell, 1980c)

| Carbohydrate source[1] | Estimated from changes in dietary ME | Estimated on basis of apparent digestibility[2] |
|---|---|---|
| Starch | 9,714 | 8,497 (90.6%) |
| Sucrose | 10,071 | 8,210 (87.6%) |

[1] Constituted 47% of the diet.
[2] Apparent digestibility x gross energy of yellow grease (9,375 kcal/kg). Digestibility coefficients are shown in parentheses.

These values were considerably higher than those obtained when the carbohydrates constituted only 20% of the diet and they exceeded the gross energy of yellow grease by a substantial margin. Apparent digestibilities of fat also were determined in this experiment. When the fat digestibility coefficients were used to estimate the ME's of yellow grease, the values for the starch-based and sucrose-based diets were 8,497 and 8,210 kcal/kg, respectively.

Obviously, the two methods of estimating the ME of yellow grease yielded values that differed greatly. In these instances, fat digestibility data probably underestimated the ME of yellow grease because no adjustments were made for endogenous lipid excretion. On the other hand, the use of changes in dietary ME for calculating the ME of yellow grease (the conventional method) obviously overestimated the energy content of the fat. When viewed correlatively, the ME data derived from changes in dietary ME's caused by fat supplementation and those obtained from apparent fat digestibilities, strongly suggested that extra energy was utilized from the nonlipid portion of the diets.

Additional experiments were conducted by Mateos and Sell (1981) to determine the influence of supplemental yellow grease (YG) and carbohydrate source on rate of food passage (ROP). Two levels of YG (0% and 7%) and two sources of carbohydrates (starch and sucrose) were compared. Based on the appearance of non-absorbable markers initially and percent recovery of markers after a given interval, they demonstrated that starch-based diets had a slower rate of passage than sucrose-based diets. Furthermore, the presence of YG slowed ROP of both diets but the ROP of sucrose diets was decreased more by fat supplementation than was the starch diet. According to the authors, these results may help in understanding the nature of the extra metabolic or extra caloric effect of fat in poultry diets. With decreased rate of passage the diet will be more thoroughly digested and absorbed and thereby more energy may be derived from a diet when fat is added.

This was confirmed in studies by Reid (1983), at the University of Arizona, who measured the ROP of feed in laying hens using tallow levels up to 8% (Table 7). There was a progressive delay in ROP with increasing levels of tallow in the ration. Wheat bran did not alter the ROP significantly.

TABLE 7. Tallow and feed passage time (Reid, 1983)

| Dietary | Half-life (hrs)[1] |
|---|---|
| Basal | 3.09 |
| 2% Tallow | 3.27 |
| 4% Tallow | 3.45 |
| 8% Tallow | 3.69 |
| 4% Wheat bran | 2.98 |
| 8% Wheat bran | 3.12 |

[1] Time required to recover 50% of the markers used to identify the feed.

In later studies at Arizona, (Maiorino *et al.*, 1986) laying hens were employed to study the effects of carrier on the TME of tallow and conversely the effects of tallow on nutrient utilization. Corn, milo, soybean meal, wheat bran, and dehydrated alfalfa meal were tested with tallow in a modified TME procedure. Laying hens were trained to consume their daily feed in two 1-hr periods/day. Each of the feedstuffs was fed alone or supplemented with 2, 4, or 6% tallow. Diets and excreta samples were analyzed for gross energy, protein, starch, amino acid, fat, and fatty acid composition to determine the effects of added tallow on the utilization of these nutrients. The TME of the added tallow in each instance was estimated.

The results are shown in Table 8. One of the theories for the "extra-caloric" effect of fat is that fatty acids of supplemental fat are better absorbed due to unsaturated fatty acids in the feed ingredients. The fat present in both corn and milo was highly available, 76.2% for corn and 83.7% for milo; while the residual oil in soybean meal was only 36.9% available. In each case, availability of total dietary fat increased as tallow was added at levels of 2, 4, or 6%. The calculated availability of added tallow was 101.8% in corn mixtures, 95.8% in milo mixtures, and 107.3% in soybean meal mixtures, indicating a synergistic effect with corn and soybean meal. Each of these improvements with tallow was statistically significant. Starch and protein utilization in these carriers was unaffected by tallow supplementation.

Addition of tallow to wheat bran significantly (P<.05) increased the retention of both fat and protein. Protein retention increased from 45.4% for the unsupplemented wheat bran to above 80% with either 4% or 6% added tallow. Total fat retention was also increased from 63.2% for the unsupplemented carrier to 86.1% with 6% tallow. Calculation of tallow availability yielded a value of 102.9%. TME of tallow in this mixture was 13.62 kcal/g (47.6% more than the gross energy).

With dehydrated alfalfa meal, starch, protein, and fat retentions were all significantly (P<.05) increased with tallow supplementation. The availability of tallow was 90.0% in this mixture and the TME of tallow was 11.18 kcal/g (21.1% more than the GE).

This study demonstrates that added fat interacts with both the residual fat in the basal ration and the non-lipid components to provide an extra metabolic effect. The extent of the interaction with the various dietary components varies with different carriers and is not always predictable.

The value of added fat in the utilization of low energy ingredients takes on added significance in those areas of the world or under conditions where high quality ingredients are unavailable or uneconomical.

TABLE 8. Effects of tallow on nutrient utilization from corn, milo, and soybean meal by laying hens (Maiorino *et al.*, 1986)

| Carrier | % Tallow |  |  |  | Estimated tallow value |
|---|---|---|---|---|---|
|  | 0 | 2 | 4 | 6 |  |
| Corn |  |  |  |  |  |
| Starch retention, % | 96.5 | 98.2 | 97.6 | 97.9 | --- |
| Fat retention, % | $76.2^{a}$ | $81.2^{b}$ | $87.4^{a}$ | $88.5^{a}$ | 101.8 |
| TME, kcal/g | 3.55 | 3.63 | 3.71 | 3.86 | 8.59 |
| Soybean meal |  |  |  |  |  |
| Starch retention, % | 79.5 | 77.9 | 81.5 | 77.9 | --- |
| Fat retention, % | $36.9^{f}$ | $56.5^{e}$ | $74.0^{d}$ | $78.7^{c}$ | 107.3 |
| Protein retention, % | 42.5 | 47.6 | 45.7 | 44.1 | --- |
| TME, kcal/g | 2.97 | 3.09 | 3.18 | 3.22 | 7.19 |
| Milo |  |  |  |  |  |
| Starch retention, % | 97.7 | 97.8 | 97.7 | 97.5 | --- |
| Fat retention, % | $83.7^{b}$ | $88.3^{a}$ | $88.9^{a}$ | $89.4^{a}$ | 95.8 |
| Protein retention, % | 99.6 | 98.8 | 97.0 | 98.4 | --- |
| TME, kcal/g | 3.58 | 3.66 | 3.75 | 3.84 | 7.93 |
| Wheat Bran |  |  |  |  |  |
| Starch retention, % | $78.5^{a}$ | $75.5^{a}$ | $76.1^{a}$ | $75.4^{a}$ | --- |
| Fat retention, % | $63.2^{d}$ | $74.8^{c}$ | $80.0^{b}$ | $86.1^{a}$ | 102.9 |
| Protein retention, % | $45.4^{c}$ | $64.7^{b}$ | $85.5^{a}$ | $81.5^{a}$ | --- |
| TME, kcal/g | 2.02 | 2.06 | 2.55 | 2.63 | 13.62 |
| Dehy. Alfalfa Meal |  |  |  |  |  |
| Starch retention, % | $63.9^{c}$ | $67.1^{b}$ | $74.3^{a}$ | $66.5^{b}$ | --- |
| Fat retention, % | $34.5^{d}$ | $51.6^{c}$ | $63.6^{b}$ | $66.7^{a}$ | 90.0 |
| Protein retention, % | $68.2^{c}$ | $79.9^{b}$ | $84.4^{ab}$ | $88.7^{a}$ | --- |
| TME, kcal/g | 1.97 | 2.34 | 2.40 | 2.56 | 11.18 |

[a-d] Means not having common letter superscripts are significantly different (P<.05).

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