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LARRY E. DAVIS
Technical Director

2250 E. DEVON AVENUE
DES PLAINES, ILLINOIS 60018
AREA CODE 312—827-0139

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THE EFFECTIVE ENERGY VALUE FOR FATS REQUIRE INTERPRETATION FOR POULTRY RATIONS

Henry L. Fuller and N. M. Dale
University of Georgia, Athens, GA

The extra-caloric effect of fat described by Carew and Hill (1964), Touchburn and Naber (1966) and Jensen et al. (1970) was attributed largely, if not entirely, to the associative dynamic effect (ADE) of fat.

This effect was first demonstrated by Forbes and Swift (1944) and results from a reduction of the heat increment or heat loss that occurs when the nutrients are fed in combination, compared with the sum of the ADE's of the individual nutrients. The greatest saving in heat loss occurred when the combination of nutrients included fat. This phenomenon is measureable as an increase in net energy as a result of improved utilization of metabolizable energy and will account for a substantial part of the extra-caloric effect when the latter is based upon performance, such as energy retention or gain.

In an experiment with broiler chicks, DeGroote (1969) observed the net availability of the ME from glucose, corn oil and soybean protein for maintenance plus growth to be 77.9 $\pm$ 4%, 88.2 $\pm$ 2.4% and 61.1 $\pm$ 6.5%, respectively, or in relative terms 100, 113 and 78.

Carew and Hill (1964) demonstrated that replacement of dietary carbohydrate with corn oil increases the efficiency of energy utilization by chicks (Table 1). In those experiments, they determined the ME of the diets containing corn oil to avoid confusing the net energy effect with that of increased metabolizable energy. Furthermore, the use of corn oil in semi-purified diets lessened the possibility of interaction at the level of absorption as demonstrated by Dale and Fuller (1981). They concluded that the beneficial effect of corn oil on efficiency of energy metabolism is mediated through the heat increment rather than the basal component of heat production.

In work with laboratory rats, Chudy and Schiemann (1969) demonstrated the interaction between dietary fat and the non-lipid components of the diet at the net-energy level (Table 2).

The effeciency of utilization of the energy of corn appeared to depend on the presence or absence of fat in the basil diet, the energy of the corn was used to meet the need for maintenance energy, permitting the fat to be used preferentially for fat storage, which is an energetically efficient process. This provides a clear explanation of the associative dynamic effect of fat-containing diets.

EXTRA-METABOLIC EFFECT: Metabolizable energy values, as usually reported, underestimate not only the net energy but also the metabolizable energy of dietary fat.

The greater-than-expected improvement in metabolizable energy resulting from supplemental fats was termed "extra-metabolic effect" by Horani and Sell (1977) to differentiate it from the net energy effect of the reduced heat increment.

It is important to remember that the ME of a dietary ingredient such as fat is not a direct measurement but is determined by substitution; therefore, it is a measure of the effect of the 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 metabolizable energy value of the test fat. It doesn't really matter to the animal or to the feed formulator whether this is a direct effect or an indirect one if this effect could be counted on to remain consistant.

The effective metabolizable energy is highly variable and dependent upon all of those factors that affect absorbability. These are usually excluded from metabolizable energy determinations insofar as possible for the sake of precision and repeatability, but often at the expense of applicability,

It appears that there are at least two phenomena involved, both of which exert their influence at the absorption level and are, therefore, measurable as increased metabolizable energy attributable to the supplemental fat (Sell, 1981; Dale and Fuller, 1981). The first of these is a synergism between the supplemental or test fat and the residual or basal fat in the test diet (Sibbald et al., 1961; Young and Garrett, 1963; Lewis and Payne, 1966, and Sibbald and Kramer, 1978). Secondly, the test fat may improve the absorbability of the non-lipid portion of the test diet as demonstrated by Mateos and Sell (1980).

Both of these phenomena would result in increased dietary ME attributable to the supplemental fat.

Sibbald et al. (1961) demonstrated the synergistic effect between two sources of fat (Table 3). Tested individually, soybean oil and tallow had ME values of 8.64 and 6.94 kilocalories per gram, respectively. When fed together in a 1:1 ratio, the mixture was found to provide 8.41 kilocalories of ME per gram. If the soybean oil remained unchanged, the tallow would have to contain 8.36 kilocalories per gram under these conditions.

Sell et al. (1976) found that changes in determined ME's of rations due to added fat consistently exceeded changes expected on the basis of calculated ME's indicating that the reference value for animal tallow, which is often used in feed formulation (7,480 Kcal/kg), underestimates the actual ME of this energy source for laying hens. Table 4 shows the apparent ME of fat based on changes in ration ME's when fat was added to corn, oats or barley rations. The values varied from 9,200-10,375 kcal/kg, depending upon the grain component when used at 2-6% of the ration.

An effective demonstration of the interaction between supplemental fat and the non-lipid dietary constituents was reported by Mateos and Sell (1980).

Yellow grease was tested at 7% in semi-purified diets containing starch or sucrose. Based on dietary ME values determined experimentally, the ME's of the yellow grease were estimated to be 9,714 and 10,071 kcal/kg for the starch- and sucrose-based diets, respectively (Table 5) When apparent digestibility coefficients of the fat were used to estimate the ME's (GE x apparent digestibility), the values were considerably lower.

It was pointed out that using apparent digestibility data probably underestimated the ME of the fat because no allowance was made for endogenous lipid excretion. A comparison of the results obtained by the two methods, however, provided strong evidence that supplemental fat resulted in extra energy being obtained from the non-lipid diet constituents.

TABLE 1. Apparent Value of Corn Oil For Deposition of Tissue Energy Gain (Carew and Hill, 1964)

Determined ME/g fat	Calculated ME/g fat	
	Exp. 1	Exp. 2
	(kcal)	(kcal)
8.8[1]	9.4 (100)[2]	10.9 (20)[3]
	11.0 (75)	12.1 (10)
	10.9 (50)	

[1]Calculated by assuming the same ME would be required per unit of tissue energy gain in all diets.
[2]( ) Levels of intake.
[3]( ) Percent corn oil in the diet.

TABLE 2. Effect of Basal Diet On the Energetic Efficiency of Fat and Corn

	Basal Rations		Supplemented Rations	
Ingredient	1	2	3	4
Common (PVM)	2.0	2.0	2.0	2.0
Corn	7.1	2.35	7.1	11.85
Fat	—	2.0	2.0	—

Suppl. 3 *vs* Basal 1 (+ 2.0 fat) = 90.0% Efficiency
Suppl. 3 *vs* Basal 2 (+ 4.75 corn) = 90.4% Efficiency
Suppl. 4 *vs* Basal 1 (+ 4.75 corn) = 73.4% Efficiency

Efficiency of utilization of ME calculated from difference in energy retention between supplemented and basal rations (from Chudy & Schiemann, 1969).

TABLE 3. Apparent ME of Tallow, Soybean Oil And a Mixture of the Two (Sibbald *et al.* (1961)

Protein Level	24.4%		34.0%		
Fat Level	10%	20%	10%	20%	Av.
			kcal/g		
Kind of fat					
Tallow	6.02	7.24	6.79	7.69	6.94
Soybean oil	8.65	8.22	8.94	8.02	8.46
Mixed fat 50:50	8.11	8.31	8.82	8.41	8.41

TABLE 4. Apparent ME of Fat, Based on Changes in Ration's ME's Attributable to Fat Supplements (Sell *et al.*, 1976)

Grain Component	Apparent ME[1]
Corn	10,300
Oats	10,375
Barley	9,250

[1]Apparent ME of animal tallow, based on changes in measured ration ME's (Ref. ME value of tallow = 7,480).

TABLE 5. Influence of Carbohydrate Source and Method Of Estimation on ME of Yellow Grease (Mateos and Sell, 1980d)

Carbohydrate Source[1]	ME of Yellow Grease, kcal/kg: 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 parenthesis.

They concluded that the higher ME values determined from changes in dietary ME's were related to the effects of supplimental fat on rate of food passage and subsequent improvement in digestability of the diets.

When using book values for the metabolizable energy of fats, the fat content and composition of the other components of the ration are often overlooked.

For instance, in a corn-soy diet with no added fat, the total fat content is approximately 2.5-3%, most 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. Even in broiler finishing diets employing high levels of animal fats, the unsaturated to saturated ratio of the total dietary fat would probably be in the neighborhood of 2:1 or greater.

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 6). When added to the corn-based diet, the TME of the tallow was 10.51, 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.

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). The TME's of two samples of blended fats and one sample of tallow were 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 to test fat ranging from 0:15% resulting in ratios of basal to test fat ranging from 0:15 up to 10:1.

The results of these experiments are shown in Table 7. 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.

It is unlikely that a wider ratio than this would be encountered ordinarily in practical feed formulation since this would permit the addition of 5 or 6% supplemental fat in a practical corn-soy ration.

A ratio of basal fat to supplemental fat of 1:1 would be more typical of feeding practice in the broiler industry. At that ratio, the unsaturated to saturated fatty acid ratio in the diet containing tallow was 2.2:1. Ratios of that magnitude should permit maximum absorption of the long-chain saturated fatty acids, according to the reports of Young(1961) and Young and Garrett (1963)

As pointed out by Dale and Fuller (1963), both the AME and TME of fats have been reported to be inversely related to level of inclusion in the test diets; however, the energy values of fats have not been adequately investigated at practical levels of dietary inclusion in the range of 2-5%. When such levels are used in ME assays, the multiplication of errors introduces a great deal of variation when extrapolating to 100%, yet it is at these lower levels that an interaction might be expected between supplemental fats and those present in the dry feed ingredient.

A series of experiments was conducted at the University of Georgia to compare the TME of corn oil and two samples of tallow varying in stearic acid content when assayed at a practical dietary level (2.5%) and to confirm or verify these values with actual absorption data. To quantitate any improvement in the TME of the test fats when assayed under practical conditions, the three test fats were also assayed at a 15% level of inclusion in the glucose-corn starch basal. To reduce the standard errors that would otherwise be otained when extrapolating results from 2.5% levels of inclusion to 100%, 40 roosters were used in each TME determination.

The results of these experiments are summarized in Table 8. There were no significant differences among the TME values of corn oil and the two samples of tallow, which varied widely in steric acid content 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 a purified basal diet the TME of corn oil was significanly higher than that of the tallows as would be expected from literature values.

There was no significant differences in fatty acid absorption between adult roosters and 8-9 week-old broilers (Table 9), which offers further evidence that the conditions imposed during the TME assay provide a satisfactory model for determining TME values for chickens reared under practical conditions.

Little attention has been paid to the energy value of competing sources of energy, namely corn and other grains. In feed formulation, particularly in the Southeast, the cost per calorie from fat is compared with the cost per calorie from corn, with appropriate compensation for the other attributes of both. Commonly used tabular values for corn range from 3,335-3,385 kcal ME/kg (1,516-1,540 kcal/lb.). Substantial evidence is accumulating that place the ME value for corn near 3,120 kcal/kg (1,420 kcal/lb.). Obviously when the energy content of corn is overestimated, the value of fat as a competing energy source is reduced.

The same result occurs when the energy contribution of fat is underestimated, and of course the error is compounded when both occur.

We are fequently asked what energy value should be used for animal fats in practical poultry rations. Looking at the data just presented, we find values ranging mostly from 9,000-10,000 kcal/kg and even greater.

Since Most of these values exceed the gross energy of fat, it would be a misnomer to call them metabolizable energy in any of its forms. They might better be termed "effective energy values", since they represent the direct or indirect energetic contribution of added fat and they are real values as far as the consuming animal is concerned.

Why not start with the gross energy value of fat, which is constant for any given fat at or near 9,400 kcal/kg? This value lies within the range of effective energy values and seldom would vary more than 5% from appropriately determined values. This would be a good starting point.

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 the ME value.

TABLE 6. Effect of Dietary Level and Basal Diet On TME of Beef Tallow (Kcal/kg) (Sibbald and Kramer, 1978)

	Level of dietary inclusion (%)		
Basal Diet	5	10	15
Wheat:soy	8.46 ± 0.31[1]	8.02 ± 0.14	7.90 ± 0.14
Corn:soy	10.51 ± 0.36	9.18 ± 0.21	8.09 ± 0.20
Wheat:soy:meat	8.40 ± 0.46	7.72 ± 0.19	7.55 ± 0.21
Wheat:soy:fish	8.78 ± 0.40	8.18 ± 0.34	7.72 ± 0.13
Mean	9.04	8.28	7.82

[1]Standard error of means.

TABLE 7. Effect of Ratio of Basal Fat to Test Fat On the TME of Test Fat (Fuller and Dale, 1982)

Basal Fat		Test	Basal Fat	TME of Test Fats		
Added[1]	Total	Fat	Test Fat	A (blend)	B (blend)	C (tallow)
%	%	%	Ratio	kcal/g	kcal/g	kcal/g
—	Nil[2]	15	—	9.04	9.76	8.26
—	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

[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.

TABLE 8. TME of Test Fats as Determined With Purified and Practical Diets (kcal/g) (Dale and Fuller, 1982)

		Tallow	
	Corn oil	Low 18:0	High 18:0
Basal Diet			
Practical[1]	10.91 ± 0.39[3]	10.51 ± 0.50	10.61 ± 0.41
Purified[2]	8.91 ± 0.18	7.79 ± 0.29	7.42 ± 0.25

[1]Assayed at 2.5% in corn-soybean meal basal diet.
[2]Assayed at 15% in glucose-corn starch basal.
[3]Standard error of mean.

TABLE 9. Fatty Acid Absorption by SCWL Roosters And 8-9-Week Broilers (%)[1] (Dale and Fuller, 1982)

	Corn oil		Low 18:0		High 18:0	
Fatty acid	SCWL	Broilers	SCWL	Broilers	SCWL	Broilers
16:0	93.5	99.1	95.2	99.4	96.2	99.1
18:0	—	—	97.4	101.2	96.5	100.0
18:1	93.9	96.8	96.2	98.2	95.5	98.1
18:2	95.4	94.1	94.3	92.2	94.9	92.4
Total fat	94.6	95.8	94.8	96.7	95.5	96.8

[1]Corrected for endogenous fat excretion.

CONSLUSION:

In most mixed feeds, the metabolizable energy (ME) can be used to predict the performance of an animal with reasonable accurancy when appropriate energy:nutrient ratios are employed.

This is because, in practical situations, there are enough inaccuracies to counter-balance one another, or in other words, where two wrongs tend to make a right. For instance, it has been well established that any measure of metabolizable energy underestimates the net energy value. In most practical rations, these tend to offset one another.

It is in rations containing high levels of fat, however, that predictions of performance become skewed. This property of fat makes it difficult for the feed formulater to place an economic value on the supplemental fat based on its energy value.

CONLUSION (Cont.'):

Furthermore, in efforts to make diets isocaloric, researchers often add increments of fat based on published ME values on the assumption that this will remove the energy variable.

Accordingly, if fats provide a real energetic effect greater even than gross energy, then diets that are assumed to be isocaloric may still contribute unequal amounts of energy that should be considered in interpreting treatment effects.

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