TRUE METABOLISABLE ENERGY (TME) AND THE ALTERNATIVE

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SUMMARY

Reappraisal is made of two recently developed methods for determining metabolizable energy of poultry feeds and ingredients. The true metabolizable energy (TME) method appears to be useful for the measurement of the energy content of oils and fats. The major criticism of the TME method is that endogenous excreta energy of starved cockerels used in computing' TME may not always correspond to that of fed birds. Experimental data are presented to illustrate that-feedstuffs do not always give the same intercept value for endogenous excreta energy; this may be different from that of starved birds.

The rapid method for determining metabolizable energy (ME) compares favourably for a range of feeds and ingredients, with other methods of determination. Collection of excreta is not extended from 24 'to 32 hours. In a recent publication, independent comparisons made between the TME method and the rapid ME method favoured the latter.

INTRODUCTION

At a previous Nutrition School (Farrell 1977) I outlined the basis of Sibbald's true metabolizable energy (TME) system (Sibbald 1976) and introduced a new, rapid method of determining apparent metabolizable energy (ME) of poultry feeds and feedstuffs (Farrell 1978). Modifications have been made to both methods in the light'of further research. In this paper a critical assessment is made of TME and its usefulness as a method of assay. There is discussion of the rapid method which includes comparison made with the conventional method of determining ME.

The current situation is that energy requirements of poultry are still expressed in terms of apparent metabolizable energy (ARC 1975; NRC 1977) as are the energy concentrations of feed ingredients.

TRUE METABOLIZABLE ENERGY

In recent years Sibbald (1977a,b) has argued for the introduction of a TME system (Sibbald 1976) in which an attempt is made to separate the excreta originating from the feed from that which is endogenous in origin. In fowl, the latter stems from endogenous urine and metabolic faeces. At this stage the two important reasons for making a correction for endogenous excreta energy appear to be (i) that if food intake of the bird is low due to poor acceptability, then the endogenous excreta become a disproportionate component of the total excreta and the apparent metabolizable energy (ME) value is depressed (Guillaume and Summers 1970), and (ii)' endogenous excreta are probably not constant but are to some extent characteristic of the bird and may be of the diet. Using the endogenous excreta output (if it can be determined accurately) of the same bird when starved to correct its total excreta output although plausible, may not give the true correction value.

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One of the key questionsin the TME system lies in the validity of the estimation of the endogenous excreta voided. For the adult, starved cockerel there is considerable variation in excreta energy. Values may range from 7.9 to 19.6 kcal/day (Farrell 1978) and differences in body weight and weight loss during starvation can only explain a small amount of this variation (Sibbald and Price 1978). Indeed we have found that even for the same cockerel, day to day variationin endogenous excreta output is considerable (Farrell 1977, unpublished data). Because endogenous excreta are probably related to metabolic rate which increases with decreasing ambient temperature it would be expected that endogenous excreta increases with decreasing temperature.. The observations of' Farrell and Swain (1977) are given for starved broilers in Table 1.

TABLE 1 Effect of ambient temperature on endoqenous excreta of starved individual broiler chickens (1 kg)

	Ambient temperature (^{o}C)					
	35	30	22	16	9	2
Endogenous excreta Kcal/24 hour	11	13	15	16	17	18
Number of observations	8	8	4	8	8	7

(From Farrell and Swain 1977)

Another important question is the validity of using endoqenous excreta of starved birds as representative of the endogenous component of birds when fed, and its verification by experimentation. Sibbald (1976) regressed energy voided as excreta against feed consumption for a range of feedstuffs. The zero intercepts which give an estimate of endogenous excreta energy, 'were similar for the 12 feedstuffs tested at 9.8 kcal/day. The reason for the common intercept for the 12 equations was that 48 values from birds starved for 48 hours were included in the regression analysis. For each of the 12 feedstuffs tested observations of fed birds ranged from 17 to 7, thus the addition of the 48 values for birds receiving no feed 'forced' theintercepts of the equations through a common origin. This approach did not allow meaningful statistical testing of individual equations to determine if the Y intercepts gave different values for individual equations. Such an approach would provide answers to the proposal that specific ingredients may influence endogenous excreta, and the use of starved birds to provide this value would therefore be inappropriate. Edmundson (personal communication 1977) observed that at least for one feedstuff, soybean meal, the intercept was different from other diets tested, and gave a value that was higher. Furthermore, the level of intake of Sibbald's (1976) birds was low and did not usually exceed 30g per cockerel because of the force-feeding procedure. used. As a consequence, the regression equations derived by Sibbald (1976) for the various feedstuffs did not have particularly impressive correlation coefficients (r) although the number of observations exceeded 50 for each feedstuff. For example, for corn r was 0.85. Without the inclusion of the 48 observations of starved birds variation would have been even greater.

As indicated the TME method as originally described by Sibbald (1976) involved the force-feeding of a pelleted feedstuff or diet (30-40g) to adult cockerels that had been starved for 21 hours. After 24 hours the 'excreta voided are collected quantitatively. This in itself is difficult

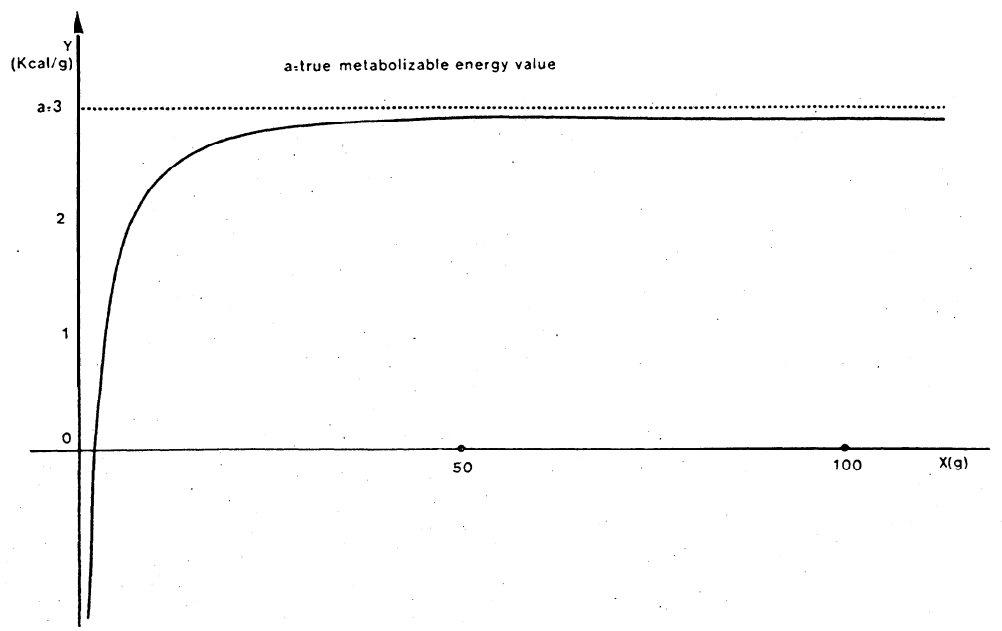
when one considers that for some feeds the dry excreta originating from the feed may be only '5 or 6 g from an intake of 30 g, together with 3 to 4 g of endogenous excreta. A weight-paired, unfed cockerel, was used in the original method to provide a measure of endogenous excreta energy voided during the 24 hour collection period. The calculation is as follows:

$$\text{TME (kcal/g)} = \frac{(\text{GE of feed} \times \text{intake}) - (\text{GE of excreta of fed bird} - \text{GE of excreta of starved bird})}{\text{Weight of feed fed}}$$

It is self-evident that the force-feeding procedure allows a precise but limited feed input of about 30-40 g. Because total excreta output is comparatively small, say 25 kcal from a cereal grain, it is absolutely essential therefore to make a correction for endogenous excreta, which may amount to 40% of excreta energy, if meaningful values are to result. The only meaningful energy system under these rather special circumstances is TME.

To illustrate the point, shown in Fig. 1 is the relationship between the apparent metabolizable energy obtained at various levels of intake for the same ingredient. The smaller the amount of ingredient offered the lower will be the ME value. Correction for endogenous excreta at any intake will allow calculation of the TME of the ingredient. Below about 50 g of feed there is a rapid decline in the ME value for the same ingredient, but above this amount there appears to be no good reason for such a correction since TME is greater than ME by essentially a constant amount. It is clear from the example given that TME is extremely sensitive to the value used for endogenous excreta. If the value does not apply specifically to the fed bird under the experimental conditions, then a precise TME of that feed ingredient can not be obtained.

FIGURE 1 Relationship between apparent metabolizable energy value (y) and food intake (x)



From Guillaume and Summers (1970)

Although in principle the conventional method of determining metabolizable energy of feeds with growing chickens fed the test diet has many disadvantages, because of cost, large sample size, high labour input etc. (Sibbald 1975a) the only real advantage of TME, as developed by Sibbald (1976) is that fats and oils can be force-fed in relatively large amounts (Sibbald 1978; Halloran and Sibbald 1979; Sibbald and Kramer 1978, 1980b). In contrast, only relatively small amounts (10-15%) can be added to a basal diet using conventional methods of determination: consequently ME is likely to be variable (Guirguis 1976). It would seem that TME has got considerable advantage over other methods when fats and oils are being investigated. Not only is it possible to introduce exact amounts of lipid into the crop but it is possible to examine effects of combinations of different fats and oils on TME (Sibbald and Kramer 1978). Even then there is doubt about the validity of correction for metabolic lipid excretion since this "may be influenced by the nature and amount of diet consumed" (Sibbald and Kramer 1978).

A rather disturbing aspect of the TME method is that it has been modified such that endogenous excreta are not now collected from a cockerel weight-paired, at the same time as the fed bird. Recently six or seven control birds have been used to establish the endogenous excreta loss (Sibbald and Price 1977; Sibbald and Kramer 1980) of the fed cockerels. The real advantage of this TME system appears to be now largely lost in that a constant value is being applied to endogenous excreta which is not only known to be variable but may tend to be characteristic of individual birds and perhaps of the diet.

As stated previously there is now evidence that for some feedstuffs, when force-fed to adult cockerels, a period of 24 h is not sufficient to allow the digestive tract to be completely emptied (Sibbald 1979; Muztar and Slinger 1979). Clearly it is necessary to identify these ingredients.

There is some suggestion that TME values are less variable than ME values for a range of feedstuffs (Sibbald 1976). The basis of this comparison was bound to give misleading results, since the same cockerels given only 30-45 g of feed were used to make both measurements of ME and TME simultaneously. Sibbald (1975b) in an experiment in which birds were given different amounts of wheat, observed that as the intake declined below 45 g/day there was a decline in the ME of the wheat due to the contribution of endogenous excreta (see Fig. 1). Thus when a comparison is made between TME and ME with cockerels force-fed only 30 g/day, then TME is bound to give values with less variation than ME. Furthermore many of the ME values obtained by Sibbald (1976) do not correspond with published data. For example, the ME value for oats was 1.97 kcal/g, fish meal was 2.07 kcal/g and dextrose 2.59 kcal/g. In recent publications for many ingredients the standard error of the TME mean appears to be increasing. Reasons for this increase are that 'regurgitation of feed by force-fed cockerels can occur at high levels of input (Sibbald 1975,. 1976; Sibbald and Kramer 1980b) and excreta of food origin are not always voided during the next 24 hours (Sibbald 1979, 1980a; Muztar and Slinger 1979).

As mentioned previously a key question that has not been satisfactorily answered is to what extent, if any, does diet influence endogenous excreta output? An experiment was therefore designed in an attempt to answer this question.

ENDOGENOUS EXCRETA AND DIET

Starved adult White Leghorn x Black Australorp cockerels trained to consume their daily allowance in one hour were given each of nine pelleted' ingredients in amounts that ranged from 20 to'110 g. Excreta were collected for the next 32 hours. The regression of excreta eneray (kcal,y) in 32 hours on feed intake (g,x) was calculated for each feedstuff. Comparisons were made of the equations using analysis of variance and' covariance analysis to determine if the slopes and intercepts of the equations were different.

To determine endogenous excreta of starved cockerels, twelve birds were starved for 32 hours and excreta were collected for the next 32 hours.

Regression equations, calculated for each of the 9 ingredients are shown in Table 2.

TABLE 2 Regression of excreta energy (Y) on feed intake (X)

	Equation (Y=)	r	n	TME (Mcal/kg)
Barley	28.2 + 0.53X	0.96	18	3.38
Groats	18.4 + 0.36X	0.86	22	3.91
Oats	19.4 + 0.75X	0.85	18	3.36
Sorghum	12.5 + 0.46X	0.88	17	3.44
Soybean	20.9 + 1.51X	0.95	18	2.68
Sunflower	10.9 + 2.30X	0.97	18	1.95
Triticale	15.6 + 0.69X	0.92	17	3.23
Wheat	9.9 + 0.60X	0.95	18	3.24
Wheat pollard	27.9 + 1.49X	0.86	20	2.75

The TME value was calculated for each ingredient by subtracting from the gross energy of the ingredient the appropriate regression coefficient. When the lines were tested statistically they were significantly'different ($P<0.01$) in both slope and intercept. Thus the ingredient influenced significantly endogenous excreta. The mean value 'for the 12 starved cockerels was 18.2 kcal. Although these results are preliminary and more measurements are currently being made, it does appear that the use of 'endogenous excreta of starved birds to provide the corrector factor to obtain TME is under some circumstances inappropriate.

RAPID DETERMINATION OF ME

There is some discussion as to whether true metabolizable energy of a feedstuff is the most meaningful description of its usefulness in poultry nutritibn. As stated, the energy requirements of poultry are expressed in terms of ME (ARC 1975; NRC 1977). Secondly, it is doubtful whether a really valid argument can be raised to justify correction for endogenous excreta under normal circumstances. The requirement for energy is for metabolic processes, production and the replacement of endogenous losses. It may be useful to know the latter, but it is an integral part of the bird's energy requirement. Although it is of interest to know the true metabolizable energy of a feedstuff the present method of determining TME may not provide the answer.

The need for such a correction for endogenous excreta has been eliminated in the rapid method developed by Farrell (1978) in which adult cockerels are trained to consume their daily feed allowance within an hour. Not only does this remove the trauma of force-feeding, which may influence digestive processes, but intake is sufficiently high (80-110 g) to remove any necessity to correct for excreta of endogenous origin (see Fig. 1). Although both this and Sibbald's method are rapid and low cost, we have found that we can use adult cockersl each day on different diets because'there is apparently no need for a period of adjustment. The low cost and minimum time required to obtain results are major arguments in favour of Sibbald's TME system. These arguments also apply to the recent method developed by Farrell (1978). We have now extended our collection of excreta from the trained cockerels to 32 hours for all feedstuffs, since some feeds do not clear the digestive tract in 24 hours. In order to standardize the procedure within normal working hours we are using this elapsed time for all feedstuffs and feed ingredients.

The use of adult cockerels in the determination of metabolizable energy has a number of advantages. The birds can be used repeatedly, and we have been using the same birds for almost three years. Because they are maintaining constant weight they are in nitrogen equilibrium and this dubious correction to values measured with growing chickens for protein retention (Farrell 1979) is avoided. Values obtained are in terms of ME and compare favourably with those determined with growing chickens and those predicted from chemical composition. In Table 3 are given ME data on both calculated, predicted and determined on formulated diets and collated by Dr. T.R. Walker (personal communication).

TABLE 3 Apparent metabolizable energy (Mcal/kg) calculated, predicted and determined using the rapid method (UNE) and conventional biological method (Sydney University) for four diets

Diet	Computer Value	Predicted* Value	Determined** Rapid Method	Conventional† Method
Layer mash	2.55	2.45	2.59	
Layer pellet	2.55	2.51	2.63	
Breeder K	2.51	2.51	2.48	2.48
Broiler starter K	3.10	3.11	3.12	3.20

*From chemical analysis (N.B. Love Industries Ltd.)
**University of New England - (Farrell 1978)
†University of Sydney - (total collection)

It is quite clear from Table 3 that for formulated diets the rapid method of determination gives values that are in close agreement with those predicted from chemical composition, and those determined using groups of chickens 'and collecting excreta over several days in the conventional manner.

More recently we have completed a comparison between the rapid method using a 32 hour collection period, the conventional method (Dr. D. Balnave, University of Sydney) and ME calculated from chemical analvsis (Dr. Dai Suter, N.B. Love Industries Ltd.). There were seven diets, of these two were formulated diets used in production, one diet was a basal diet consisting of 87% corn and 8% fish meal, two diets of the basal diet (50%) + meat meal (50%) or sunflower meal (50%) and the other two diets

were all-sorghum or all-barley with mineral arid vitamin additions. All diets were pelleted. The preliminarv results are given in Table 4.

TABLE 4 Comparison of the metabolizable energy (Mcal/kg) of feedstuffs and diets using two biological and one predicted-method

Diet	Method		
	Conventional*	Rapid**	Predicted
1 BFx 3100	3.05	3.28	3.10
2 Layer pellets	2.60	2.63	2.56
3 Basal (87%Corn/8%fish M)	3.23	3.22	
4 Basal (50%)/Meat M(50%)	2.60	2.94	2.93
5 Basal (50%)/Sunflower M(50%)	2.11	2.30	2.39
6 Barley (95%)	2.82	2.73	2.72
7 Sorghum (95%)	2.89	2.92	2.72

*4 groups of 6 birds/treatment **5 cockerels/treatment

It is interesting that the major discrepancy between the two biological methods existed for diets 4 and 5 which contained unusually large amounts (50% of meat meal and sunflower meal. Intake on all diets was at least 80 g which is well above the minimum for adult cockerels necessary to obtain valid measurement of ME (Fig. 1).

Sibbald (1977a) pointed out that "if the test diet is unpalatable then feed intake will be less than that of the basal diet. This difference in feed intake-can have a profound effect on the observed A.M.E. [apparent metabolisable energy]". 'It is interesting that for these two diets (4 and 5) ME values obtained by the rapid method agree closely with those predicted from chemical composition.

CONCLUDING REMARKS

There is some doubt'about the correction used for endogenous excreta to obtain TME. It has been shown that some feedstuffs give amounts of endogenous excreta that are different from others; these are also different from the mean value obtained for starved birds.

Because fats and oils can be included in diets in only relatively small amounts, there appears to be a real advantage in the use of TME to evaluate these feedstuffs which can be force fed both singly and in various combinations.

One of the difficulties with the TME procedure as used by Sibbald is that there is no easy method of checking the values obtained. For the rapid method this is easily and frequently done. Moreover because cockerels are hungry'at the commencement of their one-hour feed acceptability has never been a problem. If an intake of over 70 g is not achieved measurement is discarded.

Perhaps the most objective way of assessing both methods discussed here is to cite the recent work of Chami et al. (1980) who compared TME and ME. Their conclusion was that "Sibbald's method (TME) is fast, but not accurate for all feed ingredients. It is questionable to regard the TME method as scientifically more accurate than conventional ME methods.

The method of Sibbald (1976) is no faster than the ME method of Farrell (1978). It may be more desirable to dilute .a basal diet with the test ingredient and determine ME according to the procedure of Farrell (1978) because excreta collection over 24,. 48 and 72 hour post-feeding gave the same ME values*'.

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