METABOLISABLE ENERGY : RECENT RESEARCH WITH POULTRY

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Summary

Formulation of diets to a specified metabolisable energy (ME) is of major importance for the productivity of broiler chickens more so than for laying hens. Historically, conventional ME bioassays were conducted on young chickens, but over the past decade the widespread use of rapid bioassays with adult cockerels has resulted in a change in the application of ME values for feedstuffs. There is considerable evidence that ME is influenced by both age of bird and assay technique, and this was briefly reviewed and new information presented. The magnitude of the effect of these factors on ME, particularly for certain Australian wheats which have low-ME due to reduced starch digestion, should not be ignored for the convenience of a rapid bioassay on adult birds. Results were given on the development and testing of a rapid broiler assay technique (RBAT), essentially an adaptation of the Farrell rapid bioassay (Farrell, 1978), in which young broiler chickens (21d and 42d of age) were trained over a 7d period to rapidly consume food. The relationship between food intake and apparent ME was investigated in comparisons between the RBAT, conventional broiler assays and the Farrell rapid assay on adult cockerels. It was concluded that the RBAT may be of considerable benefit in the formulation of diets for broiler chickens.

I. INTRODUCTION

A transition has occurred over the last decade in the measurement and application of metabolisable energy (ME) for poultry, due to the development of rapid bioassays (Sibbald, 1976; Farrell, 1978). Conventional bioassays have a number of disadvantages relative to rapid bioassays for the formulation of diets in modern poultry production, notably (1) the duration required for an ME determination, (2) labour requirements, (3) equipment and facilities required, (4) amount of sample and (5) cost.

In no other energy system for any animal species is there such a plethora of assay methods which exist for poultry, with confusion in terminology and lack of nomenclature standardization (Pesti and Edwards, 1983). There are three main types of conventional bioassays used, namely (1) Hill et al (1960), in which a glucose-based basal diet is used into which the test ingredient is incorporated'at the expense of glucose, (2) Sibbald and Slinger (1963), in which different high and low protein basal diets are used to determine the ME of cereals and protein supplements respectively, and (3) Carpenter and Clegg (1956), in which the diet is composed of test ingredient with casein in order to obtain approximately normal growth in young chickens during the assay.

All of these conventional bioassays were based on young chickens, and the ME values derived were applied to both young and adult poultry. As a consequence there was concern about the accuracy of ME values determined with young chickens for adult poultry, and a number

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of publications dealt with this problem (Lodhi et al. 1970; Petersen et al. 1976; Din et al. 1979; Engster et al. 1981).

This situation has now been reversed because of the widespread use of rapid bioassays which use adult cockerels. Hence ME values determined for adult birds are now used to formulate diets for young chickens. There are two main types of rapid bioassay, namely (1) the Apparent Metabolisable Energy (AME) Assay (Farrell, 1978, 1981), in which adult cockerels are trained to consume a test diet or ingredient in a one hour period followed by excreta collection over 42h, and (2) True metabolisable energy (TME) Assay (Sibbald, 1976; 1983) in which adult cockerels are force-fed a known quantity of test material (30-40g), excreta collected over 48h, and TME calculated after correction for endogenous energy loss (EEL) in starved birds. Although Sibbald (1982) firmly concluded that TME was superior to AME, Farrell (1981) suggested that both methods required exhaustive testing prior to widespread adoption.

The present paper sets out with three main goals, namely (1) to provide evidence that the poultry industry requires ME data mainly applicable to broiler chickens, (2) to review information of the effects of age and assay technique on ME values, and (3) to give initial results on the development of a new rapid ME bioassay specifically for broiler chickens.

II. RELATIVE IMPORTANCE OF DIETARY METABOLISABLE ENERGY FOR BROILER CHICKENS AND LAYING HENS

Broiler chickens

Farrell (1974) showed conclusively that body weight and feed efficiency of broiler chickens were dependent on dietary ME when all other nutrients were adequate and related to ME level. This was confirmed by Fisher and Wilson (1974) and Pesti and Smith (1984) in comprehensive statistical treatments of published data. The response of growing animals to energy and protein intake depend on protein adequacy (Black and Griffiths, 1975).

Black and Griffiths (1975) in young lambs found that, when protein was inadequate, nitrogen (N) balance was independent of ME intake and was linearly related to N absorption. However, when protein-adequate diets were fed, N balance was linearly related to ME intake. This model has been confirmed for growing pigs by Campbell and others in a number of studies (e.g. Campbell and Dunkin, 1981; Campbell et al. 1985). It is probable that the model is applicable to growing poultry, and, although the work of Farrell (1974) supports this, further information is required, particularly on protein and fat deposition.

In a recent experiment (Johnson et al. 1987) the response of male and female broiler chickens to increasing dietary ME in protein-adequate diets was measured. There were eight mash diets based on practical ingredients which ranged from 9 to 16 MJ AME/kg. Total lysine was maintained at 1g/MJ AME (Campbell et al. 1987) and all other nutrients were in proportion to the AME level. Each diet was fed to three replicates of each sex with 30 birds per replicate from one-day of age. Birds were housed in deep-litter pens in a temperature-controlled shed. Representative birds from each replicate were

slaughtered at different body weights to determine carcass composition, but only body weight data are available at this time.

The response to ME in terms of body weight at 42d of age and feed conversion ratio to 42d of age is shown in Figure 1. The marked effect of dietary ME on both these production parameters is clearly obvious. Interpretation is confounded as some of the effects may be due to addition of fat per se (Pesti and Smith, 1984) since some fats are known to improve body weight gain and feed efficiency irrespective of energy intake (see review by Summers, 1984), but in a practical sense this is of minor significance as fat is routinely used to increase the ME of broiler diets.

Based on these and other studies (e.g. Farrell, 1974), there is little doubt that a major source of the variation in performance observed in Australia broiler flocks is related to variation in dietary ME from those specified in formulations.

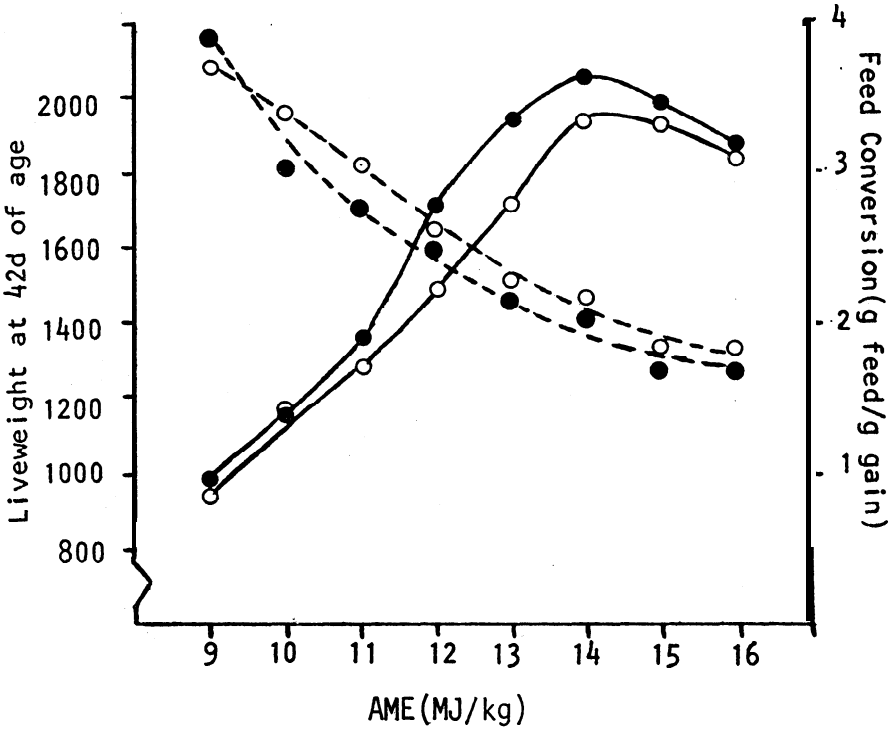

Figure 1. Response of male (●) and female (○) broiler chickens to increasing dietary AME in protein-adequate diets measured in terms of body weight at 42d of age, and feed conversion ratio (g feed/g gain) from day-old to 42d of age (Johnson et al. 1987)

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A summary of published data on the effect of dietary ME on the performance of laying hens is given in Table 1. In general, increasing the level of dietary ME caused a decrease in food intake and the feed conversion ratio (g food/g egg mass) and an increase in body weight. There was little or no effect on egg production or egg weight, The ability of laying hens to regulate ME intake with change in dietary ME depends on the strain (or bodyweight) of bird, as heavier strains overconsume ME with increasing dietary ME level (Morris, 1968).

Table 1. A summary of some published data on the effect of dietary metabolisable energy level on the performance of White Leghorn hens (Johnson, 1984).

ME content MJ/kg	Egg prod'n	Feed intake	FCR	Egg Wt.	Body Wt.	Reference
9.90-11.44	-*	+	+	-	+	Anderson et al.(1957)
10.57-12.25	-	+	+	-	-	Berg and Bearse(1956)
10.13-11.97	-	ND	+	-	+	Berg and Bearse(1958)
10.86-12.38	-	+	-	-	+	Bolton et al. (1970)
11.75-13.40	-	+	-	+	+	Combs & Helbacks(1960)
10.52-11.79	+	+	+	-	+	Harm et al. (1957)
10.59-14.27	-	+	+	-	+	Heywang & Vavick(1962)
10.19-11.46	+	+	+	ND	+	Hill et al. (1956)
10.01-12.73	-	+	+	-	-	MacIntyre & Aitken(1957)
11.14-12.24	-	+	+	-	ND	Morris & Fox (1963)
9.80-12.31	-	+	+	-	+	Petersen et al.(1960)
10.84-17.74	-	+	+	-	+	Waring et al. (1968)
10.90-11.84	+	+	+	-	ND	Daghir (1973) Expt.1.
11.38-12.15	+	-	+	+	ND	Daghir (1973) Expt.2.
10.80-12.21	-	+	+	+	ND	Daghir (1973) Expt.3.
11.30-13.81	+	+	+	-	+	Dillon (1974) Pens
11.30-13.81	-	+	+	+	+	Dillon (1974) Cages

~~* Positive (+) indicates a significant effect, negative(-) no effect~~ and ND means that parameter was not measured.

The fact that dietary ME, within the wide range of levels tested, was not a major factor influencing egg production or egg weight does not discount the likelihood that accurate definition of ME for layers may not lead to profit maximization (De Groote, 1972; MacDonald, 1983). However the conclusion can be made that accuracy of dietary ME has a greater effect on production for broiler chickens than for laying hens.

III. EFFECT OF AGE AND ASSAY TECHNIQUE ON METABOLISABLE ENERGY

Apparent Metabolisable Energy

Sibbald (1982) concluded that AME values of ingredients increase as the assay bird matures, with the change being greatest for fibrous, low-energy materials. This was based on a number of studies which showed that ME increased as young chickens grew older (Zelenka, 1968) and that adult poultry had higher ME values for the same ingredients than young chickens (e.g. Petersen et al. 1976). The latter effect was recently shown by Engster et al. (1981) for a range of ingredients (Figure 2), in that young chickens had lower ME values than laying hens and that the difference was disproportionally higher for lower energy ingredients.

Effects of age and diet form on the AME of maize, barley and wheat determined in conventional assays were found by Farrell et al. (1983). Similarly, Mollah et al. (1983) found AMEN (corrected to zero N retention) using a conventional bioassay for two wheat blends of 12.0 and 13.2 MJ/kg DM respectively for broiler chickens compared with 13.7 and 14.5 MJ/kg DM respectively for adult cockerels.

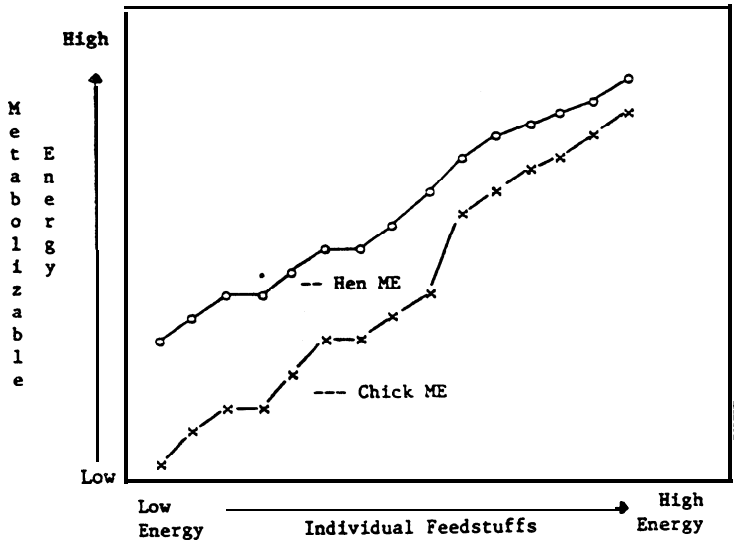

Figure 2. Apparent metabolisable energy (AME) of a range of ingredients determined for laying hens and young chickens (Engster et al. 1981)

Using the Farrell rapid assay corresponding AMEN of the two wheats were 14.6 and 14.7 MJ/kg DM respectively. These results indicate that both age and assay technique can influence the AMEN of wheat, a important consideration for the Australian broiler industry for which wheat is the major dietary cereal. This could clearly be compounded by the occurrence in Australia of certain wheats which have abnormally low ME in broiler chickens due to reduced starch digestibility (Mollah et al. 1983; Annison et al. 1987), since the Farrell rapid assay failed to detect these low-ME wheats (Mollah et al. 1983).

Farrell (1978, 1981) presented comparative AME data determined by a conventionalmethod on young chickens or using the AME rapid bioassay on adult cockerels. In general the mean values were higher for the rapid (11.96 MJ/kg) than the conventional bioassay (11.54 MJ/kg). Correction to zero nitrogen retention would increase these differences because young chickens would be in positive N balance whereas the adult cockerels would be close to zero N balance. Hartel (1986) and Sibbald and Wolynetz (1985) also found AMEN to be higher in adult cockerels than for broiler chickens.

In a recent experiment (Johnson et al. 1987) a series of eight diets were formulated with increasing AME levels from 9 to 16 MJ/kg (see Section II). These diets presented a good opportunity to compare conventional and rapid assay methods. To determine the AME of these diets each was fed ad libitum to six individually-caged male broiler chickens at both 2 to 3 weeks and 5 to 6 weeks of age with a 7d pre-feeding period followed by a 3d excreta collection period. Also, each diet was fed to five trained adult cockerels (approx. 2.5 years old) using the Farrell rapid bioassay with a 42h excreta collection period.

The results (Figure 3) show that age and/or assay technique affected the AME of practical-type diets for poultry. The inability of very young (2-3 weeks of age) broiler chickens to metabolise a high energy (16 MJ/kg) diet which contained 220g/kg of fat (mainly tallow) was probably related to poor fat digestibility (Carew et al. 1972). The rapid bioassay on adult cockerels gave values which were lower for low energy diets (9 and 10 MJ/kg) than for broiler chickens due to reduced food intakes by the cockerels on these diets (see Figure 3 insert and Section IV for the theoretical basis of this

effect). The reverse occurred in the two higher energy diets (15 and 16 MJ/kg), possibly due to a slower transit time with an increased digestibility due to high fat levels (Mateos and Sell, 1981). Also, if transit time is slowed, then excreta residues will be underestimated and hence AME overestimated in rapid assays. Much of this effect is probably due to assay technique although the possibility of higher fat digestibility (and hence higher AME values) in moderate to high energy diets in older rather than younger birds cannot be discounted (see review by Summers, 1984). Sibbald (1982) concluded that variation in AME values were probably due to variation in food intake and/or EEL. Jonsson and McNab (1983) showed that low AME of grass meal determined either by conventional or rapid assays was due to low food intake, and this was certainly the case for results shown in Figure 3. This is one of the acknowledged benefits of the TME rapid assay, which uses force-feeding.

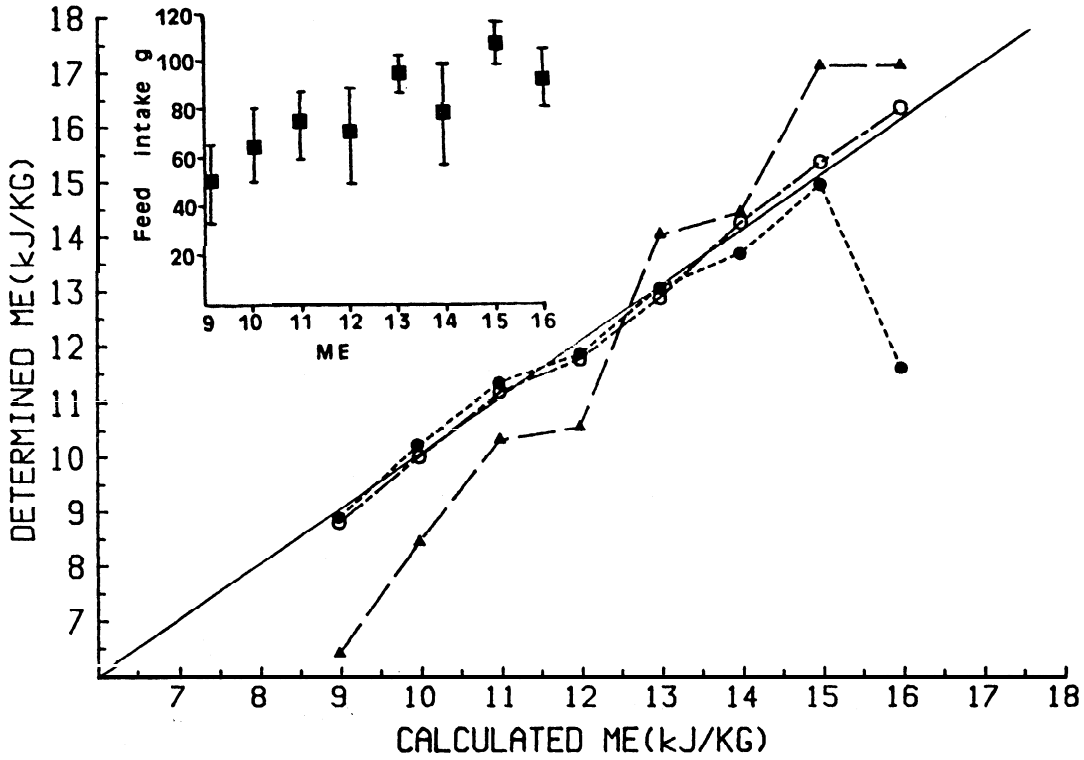

Figure 3. The AME of diets determined either using a conventional bioassay on broiler chickens at 2-3 weeks (●) or 5-6 weeks (○) of age or with a rapid AME bioassay (Farrell, 1978, 1981) on adult cockerels (▲). The solid line is the line of equality between calculated and determined values. The insert shows feed intake (g) of the adult cockerels in the bioassay.

True Metabolisable Energy

The situation regarding effects of age on TME remains uncertain. Sibbald (1978) concluded that TME values obtained with adult cockerels could be used in the formulation of diets for younger birds after investigating three ingredients, tallow, rapeseed oil and wheat shorts. These ingredients were incorporated into a basal diet in a ratio of 1:9 (ingredient:basal) and different quantities were fed to broiler chickens (10 to 30g) and adult cockerels (30g). Dale and Fuller (1980) described work which could not be statistically

analysed which indicated that broiler chickens had lower TME values over a range of ingredients than adult cockerels (Table 2). Surprisingly, Sibbald (1982) quoted these data (Dale and Fuller, 1980) as an example of a lack of effect of age on TME. Certainly Shires et al. (1980) found little differences in the TME of corn, soyabean meal, wheat shorts or alfalfa meal between young chickens and adult cockerels, but the procedure they adopted in force-feeding the birds was not the standard TME assay as described by Sibbald (1976).

Table 2. True metabolisable energy (TME, MJ/kg) values of ingredients and diets determined with adult cockerels and broiler chickens (Dale and Fuller, 1980)

	Adult Cockerels	Broiler Chickens	Difference (%)
Yellow corn	15.899	15.564	+2.1
Soyabean meal, dehulled (SBM)	11.966	12.343	-3.2
Poultry by-product meal (PBPM)	16.276	15.899	+2.3
Corn gluten meal (CGM)	18.535	18.075	+2.5
Fish meal (FM)	14.937	14.770	+1.1
Corn + SBM + PBPM	15.690	14.937	+4.8
Corn + SBM + CGM	15.774	14.937	+5.3
Corn + SBM + FM	14.477	13.640	+5.8

Indeed it seems that the approach adopted to validate the TME rapid assay is different from that used to validate the AME rapid assay. The approach used by Farrell (1978, 1981) was to compare AME rapid values on adult cockerels with conventional bioassay on young chickens, while TME rapid values on adult cockerels were compared with TME rapid values on young chickens, not with conventional bioassays (Sibbald, 1976; Dale and Fuller, 1980; Shires et al. 1980). Surely the yardstick by which all bioassays should be assessed is the conventional assay with pre-feeding of test diets as originally described (Hill et al. 1960; Sibbald and Slinger, 1963). This approach would seem sensible given that intestinal transit time is a major variable in any rapid assay (e.g. Sibbald and Morse, 1983). Until this is done conclusions on the effect of age on TME remain tentative.

IV. EFFECT OF FOOD INTAKE ON METABOLISABLE ENERGY

The key issue with regard to the development of the TME bioassay was the effect of variation of food intake on AME (Sibbald, 1976). In order to clarify the differences between TME and AME, effects of food intake must therefore be considered. AME and TME can be defined (Sibbald and Wolynetz, 1985) as:

$$AME = [IE - (FE+UE)]/FI \qquad (1)$$

$$TME = [IE - (FE+UE)+EEL]/FI \qquad (2)$$

where IE = gross energy intake (kJ)
FE+UE = gross energy output (kJ)
FI = food intake (g)
and EEL = endogenous energy loss (kJ)

With rearrangement of terms the relationship between AME and TME can be defined (McNab and Fisher, 1981) as

$$AME = TME - EEL/FI \qquad (3)$$

As discussed by McNab and Fisher (1981), equation (3) shows that for a given constant TME value, AME will depend on EEL per unit of food intake (Figure 4).

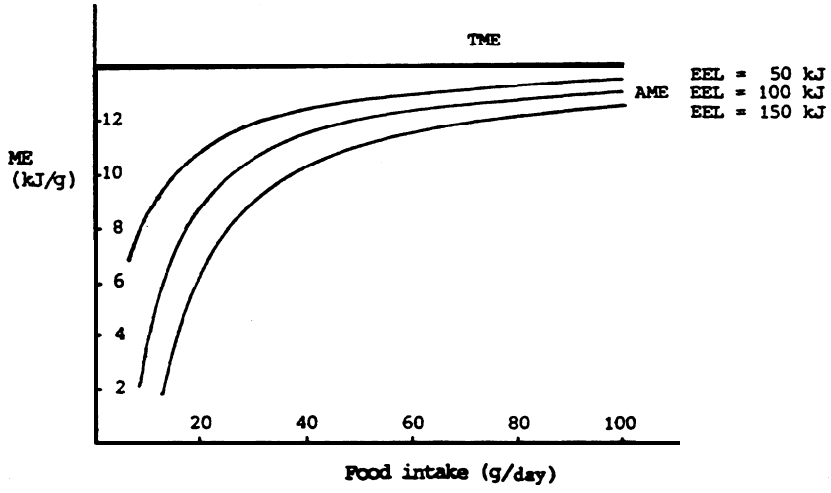

Figure 4. The relationship between food intake, endogenous energy losses and metabolisable energy (McNab and Fisher, 1981).

Sibbald (1982) suggested that this relationship (equation 3) could explainthe observed variation in AME values in a number of situations, say between young and adult poultry. However, apart from ignoring the possibility of differences in digestibility between different classes of poultry which would affect TME as well as AME, the model, and indeed Sibbald's TME assay, is based on the assumption that EEL remains constant per unit of food intake. There is good evidence that EEL is influenced by ingredient composition (Farrell, 1981), but more damaging to this assumption is that EEL is a function of energy intake (Dale and Fuller, 1982; McNab and Fisher, 1981). This has been determined by administration during starvation of a completely digestible energy source (usually glucose) (Riesenfeld et al. 1980) followed by measurement of EEL. McNab and Fisher (1981) used a 48h pre-starvation followed by 48h starvation and excreta collection either with or without 25g of glucose administration, and there was a clear reduction in EEL due to the glucose (Table 3).

Table 3. Effect of feeding 25g glucose during a 48h excreta collection period of starvation on endogenous energy loss of adult cockerels (McNab and Fisher, 1981)

Experiment	Treatment+	Endogenous energy loss (kJ/48h)#
1	Starved	139 ± 27
	Starved + glucose	71 ± 10
2	Starved	121 ± 25
	Starved + glucose	63 ± 8

+ Six adult cockerels per treatment
# Mean and standard deviation

It could be considered that EEL may be a function of energy intake since at higher levels there would be less catabolism of body reserves. Hartel (1986) found good evidence to show that with continuous feeding EEL may be low or change with food intake and approach zero when food intake approaches zero. If this is true then with continuous feeding there should be little difference between AME and TME, a fact confirmed by Hartel (1986).

V. DEVELOPMENT OF A RAPID BROILER ASSAY TECHNIQUE (RBAT) TO DETERMINE METABOLISABLE ENERGY

In Australia the use of the rapid AME bioassay on adult cockerels (Farrell, 1978; 1981) has greatly extended the amount of ME data for the poultry and stockfeed industries. However, there can be no doubt that legitimate concern still exists regarding the relativity of adult rapid values for broiler chickens.

This concern can be addressed in four ways, namely (1) by ignoring possible differences and/or using correction factors, (2) by devoting considerable time and effort in comparative studies, as was done historically to validate values for adults when bioassays were carried out on young chickens, (3) by returning to conventional assays on broiler chickens or (4) by developing a rapid bioassay specifically for broiler chickens to supplement existing rapid bioassays. The first option would be unreasonable given the evidence (see Section III), and the second and third have been suggested by Farrell (1981) and Hartel (1986) respectively.

However the fourth option is tenable because of the considerable advantages of rapid bioassays. Studies were therefore commenced at the Animal Research Institute in 1984 to investigate the possibility of developing a rapid broiler assay technique (RBAT) to determine AME. Essentially the technique is an adaption of the Farrell rapid AME bioassay on adult cockerels, and revolves around the training of young broiler chickens over a 7d period to rapidly consume a test meal. The effect of food intake on ME has been a major component of these studies. Extensive comparisons have been carried out using conventional assays on broiler chickens and with the Farrell rapid bioassay on adult cockerels. Some of this work will be described below.

Experiment 1

Introduction

The aim of this initial experiment (Johnson and Eason, 1986) was to examine a training procedure for rapid food intake in young broiler chickens (21d of age) and to determine the ME of a diet (Table 4) at different levels of food intake.

Materials and methods

One hundred and eleven day-old male broiler chickens of a commercial strain were reared in battery brooders using normal procedures in four groups of approximately equal numbers. A standard broiler starter diet was fed *ad libitum*. From 14d of age two groups were placed on a training programme of two 2-hourly feeding periods (0800-1000h and 1400-1600h) each day. At 21d of age the mean (±SD) liveweights of the trained birds (N=60) and

control birds (N=50) were 585 (±49)g and 723 (±62)g respectively. At 21d of age 48 of the trained birds were randomly selected and placed in individual metabolism cages situated in a controlled-temperature room at 22°C. Training continued to 24d of age and then, after a 42h starvation period, birds were offered for a lh period either 0, 10, 20, 30, 40 or 50 g of the test diet (Table 4). Eight birds were assigned to each of the six feeding levels. Excreta were quantitatively collected during the following 42h period, dried, ground and analysed for nitrogen (N) and gross energy

Table 4. Composition of the test diet used in metabolisable studies

Ingredient	g/kg
Wheat	500
Corn	175
Soyabean meal	250
Tallow	25
Meat and bone meal	43.5
Vitamin and mineral premix	2.5
DL-Methionine	1.5
Salt	2.5
Chemical composition	
Dry matter	879.0
Ether extract	49.4
Crude protein (N x 6.25)	226.1
Acid-detergent fibre	30.5
Ash	37.8
Gross energy (MJ/kg)	17.192

Results and Discussion

The relationship between FE+UE(Y) and IE(X) was

$$Y = 49.1 + 0.181X \quad N = 34, \; r^2 = 0.973 \qquad (4)$$

The intercept was lower than the mean (±SD) EEL determined in eight starved birds of 58(±10)kJ/42h. AME increased in a curvilinear manner as food intake increased, and TME decreased (Figure 5). Mean (±SD) AME (N=15) and TME (N=21) in the plateau regions of food intake were 12.529(±0.215) and 13.902(±0.215) MJ/kg respectively. Correction to zero N retention (36.5 kJ/g) gave an AMEN of 12.187(±0.191) MJ/kg. The mean (±SD) AME of the same diet determined using the Farrell rapid assay on adult cockerels (N=5) over a 42h collection period was 13.038(±0.155) MJ/kg.

This study showed that broiler chickens could be trained over a short period of time for a rapid bioassay. The relationship between AME and food intake was as expected from theoretical considerations (see Section IV) and variation in AME within the plateau region of food intake was acceptable.

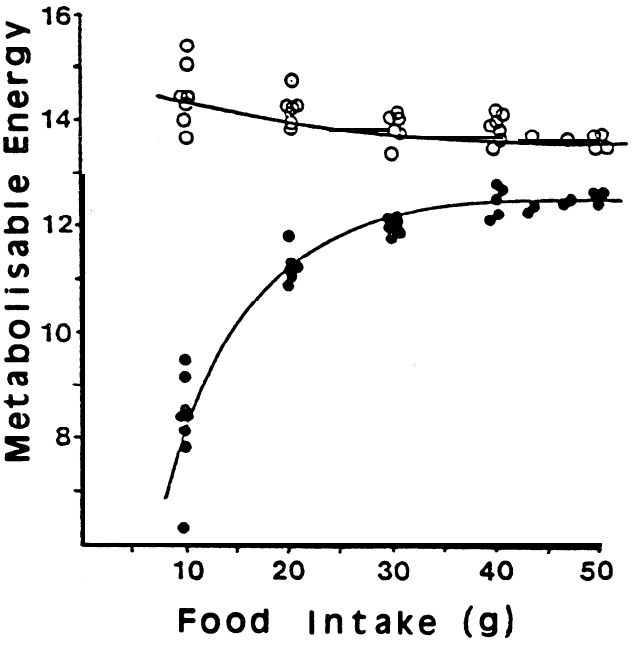

Figure 5. The effect of food intake on true (0) and apparent (●) metabolisable energy of broiler chickens in a rapid bioassay (Johnson and Eason, 1986).

Experiment 2

Introduction

Maximum attainable food intake after a 7d training schedule of broilers at 21d of age was found to be close to that required to achieve a plateau in AME (Experiment 1). Therefore the aim of Experiment 2 was to examine the effect of age (21d and 42d) on the relationship between food intake and AME, and to commence detailed comparisons with AME values determined with conventional broiler assays at 21d and 42d of age and the Farrell rapid assay on adult cockerels.

Materials and Methods

One hundred and fifty day-old male broiler chickens were reared similarly to Experiment 1. At 14d of age, 48 birds were transferred to individual metabolism cages in a controlled temperature room at 22°C. Twenty four birds (RBAT) commenced a 7-day feed training schedule as described previously (Experiment 1) using a standard broiler starter diet, and the remaining 24 birds (conventional) commenced a 4-day ad libitum pre-feeding period on the test diet (Table 4). At 21d of age, RBAT birds were starved for 42h and then offered for a lh period either 0, 10, 20, 30, 40 or 50 g of the test diet (Table 4), with four birds at each feeding level, followed by a 42h excreta collection period. After the 4d pre-feeding period, conventional birds were offered either 20, 40, 50, 60, 70 or 80g of the test diet (four birds/level) for one day then starved for 24h. The six feeding levels were then offered each day for a 3-day period followed by a 24h starvation period and excreta were collected each day, weighed and frozen prior to analysis.

A similar procedure was followed with a different group of birds commencing at 35d of age. RBAT birds were trained from 35 to 42d of age and then offered for a lh period either 0, 20, 40, 60, 80 or

100g of test diet, while conventional birds were pre-fed ad libitum for a 3d period, received either 20, 40, 50, 60, 80, 100 g of test diet for 1d, starved for 24h then offered the same feeding levels each day for a 3d feeding period followed by 24h starvation as described previously.

Adult crossbred (WL X A) cockerels about 2.5 years of age had been previously trained and used regularly in the Farrell rapid AME assay. Birds were starved for 42h then offered for a lh period either 40, 60, 80, 100, 120 or 140 g of test diet followed by a 42h excreta collection period. Six cockerels were assigned to each feeding level.

Results and Discussion

Results on the relationship between FE+UE and IE are given in Table 5. These results show clearly that AME was not influenced by level of food intake with continuous feeding, as the intercept in the relationship between FE+UE and IE was not significantly different from zero for broiler chickens in the conventional bioassay at either 21d or 42d of age. The intercept is an estimate of EEL, and since it was not significantly different from zero it follows that AME and TME would be very similar in birds fed on this diet continuously. The effect of level of food intake was observed only in the rapid bioassays. Since the intercepts in all the rapid assays were significant, the AME cannot be the same as TME. This confirms the results of Hartel (1986), who suggested that EEL determined from starved birds was an artifact which was not applicable to birds fed continuously. However, similar to Hartel (1986) the present study was limited to one diet, and it is known that diet composition can influence the effect of food intake on AME in conventional assays (Kussaibati et al. 1982).

Table 5. Linear regression coefficients for the relationship between gross energy output (FE+UE,kJ) and gross energy intake (IE,kJ) for broilers at two ages using either a rapid or conventional bioassay and for adult cockerels using the Farrell rapid bioassay

Bird	Age	Assay	Regression coefficient+ a	b	N	r^2	RSD
Broiler	21d	RBAT	51.1 (±4.9)**	0.205 (±0.010)**	20	0.960	8.5
	21d	Conventional	-0.4 (±44.8)NS	0.275 (±0.075)**	24	0.961	76.1
Broiler	42d	RBAT	81.8 (±10.8)**	0.224 (±0.010)**	20	0.963	20.2
	42d	Conventional	8.2 (±71.1)NS	0.264 (±0.011)**	24	0.962	120.8
Adult cockerel	>2y	Farrell rapid	98.6 (±7.5)**	0.180 (±0.006)**	30	0.973	16.9

+ Equation (FE+UE) = a + bIE. N is number of observations, r^2 is the coefficient of determination and RSD is the residual standard deviation. Significance of coefficients, ** $P < 0.01$, NS is not significant.

The effect of food intake on the RBAT and Farrell rapid assays is shown in Figure 6. The AME and AME_N determined by the different assay procedures are given in Table 6.

Table 6. AME and AME_N (MJ/kg) of a test diet determined by conventional and rapid broiler assays and the Farrell rapid assay on adult cockerels.

	Conventional broiler[1]	Rapid broiler (RBAT) 21d[2]	42d[3]	Rapid cockerel[3]
AME	12.534 (±0.323)	12.65	12.52	12.92
AME_N	12.132 (±0.304)	12.25	12.17	12.81

1. Mean (±SD) at 21d and 42d of age (n = 48)
2. Calculated from regression equations (e.g. Table 5) for a food intake of 50g/bird
3. Calculated from regression equations (e.g. Table 5) for a food intake of 100g/bird

The difference of 0.40 MJ AME/kg and 0.64 MJ AMEN/kg between the Farrell assay and rapid broiler assay values at 42d of age was not attributed to EEL since intercepts (Table 5) were 98.6 and 81.8 kJ respectively. Rather, metabolisability (l-b) of the diet was higher ($P < 0.05$) for the adult cockerels than the broiler chickens. Clearly the two factors suggested by Sibbald (1982) as the origin of AME differences between adult and young poultry, namely food intake and EEL, did not contribute to observed differences in the present study.

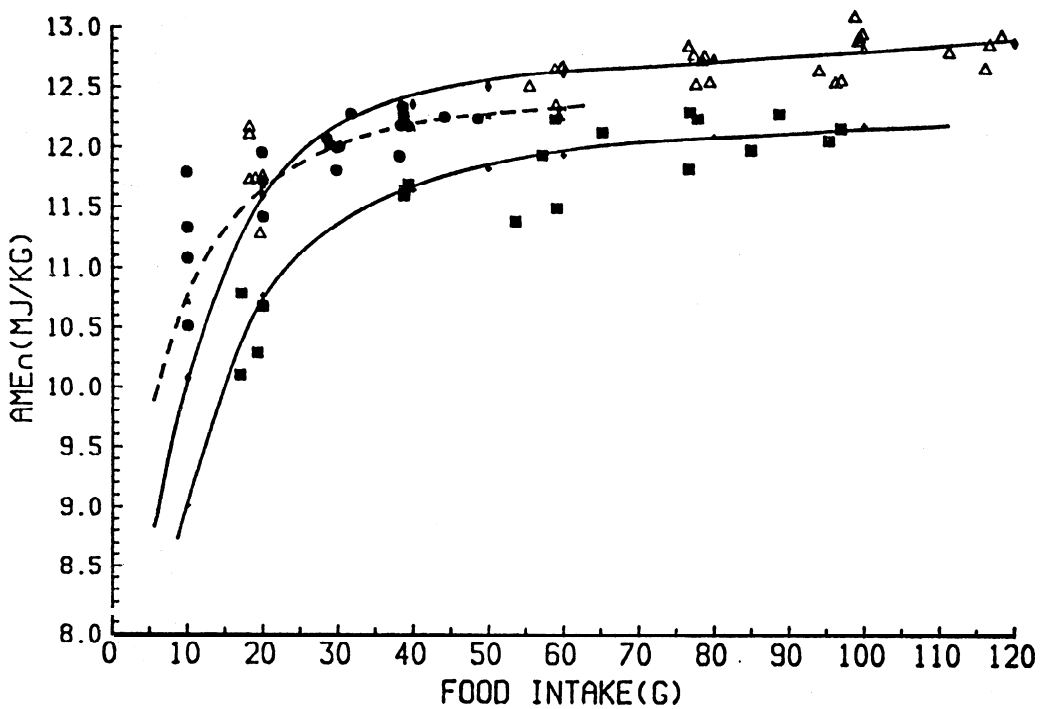

Figure 6. The relationship between food intake and apparent metabolisable energy (AME) determined in rapid bioassays with broiler chickens at 21d (●) and 42d (■) of age and with adult cockerels (A)

VI CONCLUSIONS

Dietary ME has a central role in determining broiler performance and it should be of considerable concern that there is evidence that ME values of feedstuffs are influenced by age and assay method. Up to date, the probability that ME values based on adult birds may not be directly applicable to young broiler chickens has been accepted fait accompli in order that rapid bioassays may be used for ME determinations. The recent European Table of Energy Values for Poultry Feedstuffs (1986) states " ..... values are based on work with adult birds, mainly cockerels. It is known that ME values for young birds, especially for the fat component of feeds, may be lower. However knowledge in this field in not complete enough to compose a separate table for young birds at this time." Fisher (1983) found that chemical prediction equations for AME which were derived from adult bioassays overestimated AME values for young chickens by 2.24 MJ/kg .

The present paper puts forward the argument that rapid bioassays are required by the poultry industry, and that separate ME values for young chickens and laying hens would increase the accuracy of diet formulation, Initial studies on a rapid broiler assay technique (RBAT) are particularly promising in this regard, but further tests are required. Any rapid bioassay will have some disadvantages over conventional assays related mainly to food intake and intestinal transit time, but these are not insummountable problems (Farrell 1981; Jonsson and McNab, 1983). In conjunction with these developments there is a need for standardization of nomenclature for ME (Pesti and Edwards 1983), and the effects of genetic selection of broilers on ME (Pym, 1983) indicate that broiler genotype may also require specification in the future when reporting ME data.

Ethical considerations may well play a role in determining future ME methodology. Certainly, as first discussed by Farrell (1981), it is very unlikely that Animal Ethics Committees in Australia would view favourably the Sibbald TME system where adult birds are continually subjected to a 48h pre-starvation followed by a 48h excreta collection period after a food input of just 20-30g.

The arguments put forward by Hartel (1986) concerning the validaity of the TME assay of Sibbald (1976) have in part been confirmed by studies presented in this paper (Section V). Additionally, the apparently over-looked finding some years ago that EEL is a function of energy intake (Dale and Fuller, 1982; McNab and Fisher, 1981) lends credence to the suggestion by Hartel (1986) that the TME system should be rejected since EEL is not a constant. The real goal is that biological responses of poultry can be defined in terms of an accurate and measurable energy system, and the AME system can achieve this goal. This is evidenced by the use of AMEN in broiler growth models (Fisher, 1987), and it is likely that accuracy of prediction of such models will be enhanced by using ME values derived from a broiler bioassay.

ACKNOWLEDGMENTS

The financial support of the Australian Chicken Meat Research Committee is gratefully acknowledged.

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