# The metabolizable energy content of some South African feedingstuffs evaluated with poultry

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Thirteen feed ingredients, representative of those used in the feeding of poultry and pigs in South Africa, were assayed for apparent and true metabolizable energy content (AME and TME), with at least 60 determinations being made on each ingredient. The method used was that proposed by Sibbald (1976a). A second series of investigations revealed; that a 24 h collection period was not sufficient for the complete clearance of the ingredients fed and consequently a 48 h collection period was recommended; that errors are increased when either small or large amounts of feed are given by intubation, the ideal amount being closer to 0,015 of body mass (50 g/bird) than the 0,01 recommended originally by Sibbald (1976a); that age, body-mass and environmental temperature, do not influence EEL significantly; and that the TME is not increased by improving the protein quality of a feed ingredient.

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Dertien voerbestanddele, verteenwoordigend van dié wat vir die voer van pluimvee en varke in Suid-Afrika gebruik word, is ontleed vir skynbare en ware metaboliseerbare energieinhoud (SME en WME). Op elke bestanddeel is ten minste 60 bepalings uitgevoer. Die ondersoekmetode was dié voorgestel deur Sibbald (1976a). 'n Tweede reeks ondersoeke het aan die lig gebring dat 'n 24 h versamelperiode onvoldoende was vir die volledige deurgang van die bestanddele wat gevoer is, gevolglik is 'n 48 h versamelperiode aanbeveel; dat foute verhoog wanneer of te klein, of te groot hoeveelhede gevoer word, die ideale hoeveelheid is in die omgewing van 0,015 per liggaamsmassa (50 kg/haan) in plaas van die 0,01 soos aanbeveel deur Sibbald (1976a); dat ouderdom, liggaamsmassa en omgewingstemperatuur nie die EEL (EEV) betekenisvol sal beïnvloed nie, en dat die WME nie styg wanneer die proteïn kwaliteit van 'n voer bestanddeel verbeter word nie.

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## Introduction

Metabolizable energy (ME) is the difference between the gross energy of food eaten and the gross energy of faeces and urine voided. It represents the total amount of energy supplied in the food that the animal can utilize. This measure has become generally accepted as a means of expressing food values and energy requirements in poultry nutrition (Miller, 1974). There is a large amount of literature on the ME content of various feeds determined by means of the 'classical' approach of Hill, Andersen, Renner & Carew (1960), Potter, Matterson, Arnold & Pudelkiewicz (1960) and Sibbald & Slinger (1963). Values assigned to particular ingredients vary considerably in different feed-composition tables, not only because of the differences in the chemical composition within feedstuffs, but also because of the errors involved in measuring ME by the classical method (Potter, 1972).

Sibbald (1976a) proposed a more accurate and rapid procedure for measuring the ME of feeds than the method previously used. Values obtained with this method appear not to be influenced by species, sex, strain, age or level of food intake (Sibbald 1976b; 1977a; 1978). The method takes account of metabolic energy ($FE_m$) and endogenous urinary energy ($UE_e$), the values obtained therefore being termed true metabolizable energy (TME) values, as opposed to the apparent ME (AME) values obtained when using the 'classical' method of ME determination. ME should be used only as a general term, specific values being either AME or TME depending on whether a correction has been made, in their determination, for endogenous energy loss (EEL).

The method used by Sibbald has been well documented (Sibbald 1976a,b; 1977a,b; 1978; 1979; Sibbald & Price 1977; 1978; 1980) and appears to provide rapid and reliable results on all types of feeds. Very little work has been published which presents values of the ME content of feed ingredients used in South Africa, and even less on the TME of such ingredients (du Preez, de Jong & Hayes 1979) so this study was undertaken to provide the feed industry in South Africa with TME values for the ingredients at their disposal.

Two series of experiments are reported in this paper, the first was conducted prior to the observation by Sibbald (1978) that certain foodstuffs do not clear the digestive tract within 24 h of being fed, leading to inflated estimates of TME, and to certain other anomalies which also became apparent, mostly related to the value assigned as EEL (Sibbald, 1981). Because most of the data collected during the first series of experiments were valid in spite of the above observation it was felt that these data should be published. The second series of experiments was designed to determine to what extent the above anomalies would alter the obtained values, and whether some correction factor could be applied in order to improve their accuracy.

## Materials and Methods

Adult Amber-Link roosters were housed in individual wire cages, measuring 450 × 450 mm, the height being 500 mm. Each cage was fitted with a cup-waterer, and at times other than during the assay period, food was made available in a trough in front of each row of cages. Prior to each assay birds were fasted for 24 h to empty their digestive tracts.

### First series of experiments

Sibbald's (1976a) method was adhered to when force-feeding the roosters. All ingredients were pelleted, and an amount approximately equal to one percent of their body mass was supplied to each rooster by means of a pyrex tube to which a funnel had been fused. A plastic tray below each cage was used to collect excreta voided during the 24 h balance period. These excreta were transferred to glass bottles, frozen, then freeze-dried, and once the contents had returned to equilibrium with atmospheric moisture, the mass was measured. Samples of feed and ground, freeze-dried excreta were assayed for gross energy using a Parr adiabatic bomb calorimeter.

Thirteen ingredients were assayed for both AME and TME, with at least 60 determinations being made on each ingredient. These feeds were drawn from bulk storage bins from two local feed mills over a period of one year, and can be regarded as being representative of feeds used throughout the Republic. Each ingredient was fed to six birds during each assay period, the number of birds available being 48. Assays were conducted weekly, the birds being replaced after 26 weeks of experimentation.

AME and TME of the ingredients were calculated according to the following formulae:

$$\mathrm{AME\,(kJ/g)} = \frac{(\mathrm{GE_f} \times \mathrm{FI}) - \mathrm{Ye}}{\mathrm{FI}}$$

$$\mathrm{TME\,(kJ/g)} = \mathrm{AME} + \frac{(\mathrm{FE_m} + \mathrm{UE_e})}{\mathrm{FI}},$$

where $\mathrm{GE_f}$ is the gross energy of feed (kJ/g), FI is the food input, and Ye is the energy voided as excreta.

Endogenous energy loss (EEL) was determined by fasting birds during the 24 h experimental period. Excreta collection and gross energy determinations in this case were the same as those described above.

### Second series of experiments

#### *Effect of faecal collection time on AME and TME*

Six ingredients were used in this trial, each being fed to 16 birds in two assay periods. Four of the ingredients were of animal origin, i.e. bloodmeal, carcass meal, fishmeal and poultry by-product meal (P.B.P.M.), the other two being of plant origin, i.e. lucerne meal and wheaten pollard. The quantity of pelleted ingredient fed to each bird was 30 g. Faeces were collected for 24 h after feeding, then for every 6 h period thereafter for a further 24 h. Faeces voided prior to each collection time, were kept separate from one another, and were treated in the manner described in the first series of experiments. In calculating the TME of each ingredient, the EEL in the second 24 h period was taken as 0,85 of that in the first 24 h (Mutzar & Slinger, 1980).

#### *Effect of level of feed input on AME and TME*

Three ingredients were used in this trial in which different amounts of food were placed in the crops of adult roosters. Eight samples of each ingredient were fed in ten different quantitative inputs, ranging from 5 g to 40 g in 5 g increments, then to 60 g in 10 g increments. The trial was conducted over an 8 w period, with the ten levels of each of the three ingredients being fed once each week.

The assay for AME and TME was similar to that described for the first series of experiments, i.e. birds were fasted for 24 h prior to force-feeding, and faecal collection time was 24 h.

#### *Effect of age, body mass and environmental temperature on endogenous energy losses (EEL)*

During both the first and second series of experiments, age and body mass of roosters as well as the environmental temperature at the time of each experiment were recorded, together with the EEL output of birds fasted for 48 h. These data were subjected to regression analysis to determine whether any relationships existed between them.

#### *The effect of improved protein quantity and quality on the AME and TME of maize*

Various experiments have been reported in which the additivity of the TME method of energy evaluation has been tested (Sibbald, 1977b; Du Preez *et al.*, 1979). An approach to investigating this problem other than by mixing together two or more feeds, would be to improve the protein content, or amino acid balance, of a poor quality feed such as maize and then determine whether the TME of maize is thereby improved. In this experiment the protein content of maize was increased by adding dried egg albumen in the proportion 0,90 maize:0,10 egg albumen. The second treatment involved the addition of L-lysine – HCl in the proportion 0,99 maize:0,01 L-lysine thereby improving the content of the first-limiting amino acid of maize. The amino acid balance of maize has been improved genetically in Opaque-2 cultivars and such 'high' lysine maize (Var. HL 2) was used as the third treatment in this trial, with standard yellow maize acting as the control.

A 30 g sample of each diet was fed to eight adult roosters after a 24 h fasting period, with faecal collection during the following 24 h. AME and TME were determined in the usual manner.

**Table 1** Number of samples assayed, mean gross energy and apparent digestibility of ingredients

| Ingredient | Number of Samples | Gross energy (kJ/g) | Apparent digestibility[1] (%) |
|---|---|---|---|
| Bloodmeal | 84 | 21,84 ± 0,22 | 46,32 ± 1,13 |
| Brewers grain | 90 | 17,79 ± 0,47 | 48,10 ± 1,11 |
| Carcass meal | 61 | 19,81 ± 0,36 | 48,75 ± 1,05 |
| Fishmeal | 151 | 18,04 ± 0,62 | 48,79 ± 1,05 |
| Groundnut oilcake | 112 | 17,43 ± 0,10 | 45,15 ± 4,76 |
| Lucerne meal | 77 | 15,79 ± 0,22 | 33,84 ± 2,01 |
| Maize | 174 | 16,25 ± 0,07 | 64,57 ± 1,85 |
| P.B.P.M.[2] | 109 | 20,99 ± 0,53 | 52,27 ± 1,17 |
| Ricebran | 70 | 19,71 ± 0,49 | 46,80 ± 1,16 |
| Sorghum | 161 | 16,25 ± 0,06 | 40,74 ± 1,87 |
| Sunflower oilcake | 101 | 17,67 ± 0,08 | 39,18 ± 1,48 |
| Wheat bran | 81 | 16,52 ± 0,10 | 44,10 ± 1,19 |
| Wheat pollard | 98 | 16,88 ± 0,08 | 45,31 ± 1,18 |

[1] Mean and SEM of percentage of food retained after 24 h collection period.

[2] Poultry by-product meal.

## Results and Discussion

In the first series of trials, a total of 1 369 individual assays were completed on thirteen feeds. The number of assays per ingredient, together with the mean gross energy and apparent digestibility of each food ingredient, are given in Table 1. Some of the interesting features are the very high gross energy (GE) of bloodmeal; the fact that maize and sorghum have the same GE content but vastly different digestibilities; and the low apparent digestibilities of lucerne, sunflower oilcake meal and sorghum. No account was taken of the polyphenol content of the sorghum samples used in this trial, but it is known that digestibility is adversely affected by a high polyphenol (tannin) content (Gous, Kuyper and Dennison, 1982).

During the course of the experimental period 150 birds were used to determine EEL. The mean of these observations was 17,6 ± 0,85 kJ/kg body mass in 24 h, or 46,06 ± 2,20 kJ/bird/d. These values correspond reasonably well with previous estimates, eg. 17,03 kJ/kg (Sibbald, 1976a), 21,76 kJ/kg (Guillaume & Summers, 1970) and the range 9,92 to 28,99 with a mean of 18,66 kJ/kg (Sibbald & Price, 1978). These latter authors analysed a large body of data relating to EEL and found that only 0,23 of the variation could be accounted for on the basis of differences in body mass and change in mass. The results of a similar exercise in the present series of experiments (discussed below) produced results which concur with these findings. Because the EEL values are so variable and because they do not appear to be related to those variables measured, an average value might be a more accurate estimator of EEL than would a value determined by making direct measurements simultaneously with assays of feed ingredients as suggested by Sibbald & Price (1978). Further support for this contention is provided by the experiments of Sibbald (1981) and Fisher (1982), the latter author providing convincing evidence that energy loss is linearly related to intake, indicating that both the digestibility of energy and endogenous energy losses are constant over the range of intakes tested (5 to 70 g/bird), thereby justifying the use of a single value for EEL in his study. For these reasons, the value 46,06 kJ/bird was used in calculating the TME of the feed ingredients assayed, these values being presented in Table 2.

Apparent ME values of the thirteen feed ingredients are shown in Table 2 for interest only. These values are based on small food allowances, with no correction for EEL or for faecal N, and consequently would be an underestimation of the actual AME of these ingredients. A correction is applied later to these data given in Table 7.

**Table 2** Apparent and true metabolizable energy content of food ingredients[1]

| Ingredient | AME (kJ/g) | TME (kJ/g) |
|---|---|---|
| Bloodmeal | 14,40 ± 0,23 | 16,18 ± 0,21 |
| Brewers grain | 10,32 ± 0,24 | 12,16 ± 0,24 |
| Carcass meal | 13,67 ± 0,18 | 15,72 ± 0,18 |
| Fishmeal | 13,14 ± 0,31 | 14,85 ± 0,30 |
| Groundnut oilcake | 10,06 ± 0,72 | 11,86 ± 0,71 |
| Lucerne meal | 5,89 ± 0,28 | 7,54 ± 0,27 |
| Maize | 13,13 ± 0,08 | 14,84 ± 0,08 |
| P.B.P.M. | 15,12 ± 0,29 | 16,88 ± 0,27 |
| Ricebran | 12,32 ± 0,27 | 14,17 ± 0,28 |
| Sorghum | 12,38 ± 0,11 | 14,02 ± 0,10 |
| Sunflower oilcake | 8,48 ± 0,17 | 10,27 ± 0,17 |
| Wheat bran | 8,12 ± 0,19 | 9,94 ± 0,19 |
| Wheat pollard | 9,13 ± 0,18 | 10,79 ± 0,18 |

[1] These values are uncorrected. Refer to text and to Table 7 for corrected values.

In measuring the effect of faecal collection time on AME and TME, the mass of excreta voided after 24 h constituted a considerable percentage of the total (48 h) excretion irrespective of the ingredient fed (Table 3). Differences in

**Table 3** Mass of faeces produced at 6 h intervals starting 24 h after feeding 30 g of six different ingredients

| | Hours after feeding | | | | |
|---|---|---|---|---|---|
| Ingredient | 24 | 30 | 36 | 42 | 48 |
| Bloodmeal | 12,34[1] | 1,77 | 0,26 | 0,52 | 0,48 |
| | ± 2,33 | ± 1,02 | ± 0,20 | ± 0,34 | ± 0,39 |
| Carcass meal | 13,20 | 1,77 | 0,77 | 1,33 | 0,08 |
| | ± 2,82 | ± 1,09 | ± 1,14 | ± 0,49 | ± 0,22 |
| Fishmeal | 11,86 | 1,09 | 0,08 | 1,03 | 0,47 |
| | ± 2,55 | ± 0,61 | ± 0,23 | ± 0,58 | ± 0,50 |
| Lucerne meal | 16,19 | 2,25 | 0,74 | 0,80 | 0,64 |
| | ± 5,04 | ± 1,85 | ± 0,84 | ± 0,62 | ± 0,57 |
| Poultry by-product meal | 11,34 | 1,21 | 0,60 | 0,69 | 0,50 |
| | ± 2,22 | ± 0,48 | ± 0,20 | ± 0,30 | ± 0,38 |
| Pollard | 14,13 | 0,57 | 0,24 | 0,51 | 0,35 |
| | ± 1,24 | ± 0,17 | ± 0,29 | ± 0,29 | ± 0,11 |

[1] Mean of SEM of sixteen observations.

rates of passage between ingredients were nevertheless apparent, the slowest being where carcass meal and lucerne meal had been fed, the most rapid being that of pollard. This continued excretion of energy (whether endogenous or exogenous) during the second 24 h collection period, had a pronounced effect on the AME of most of the ingredients tested, the mean AME over all six ingredients, calculated after 48 h collection, being only 0,88 of the 24 h value. In the case of lucerne meal especially, there was a significant decline in AME when the longer collection time was used.

The rate of EEL during the starvation period is not constant. It has been shown to decrease with the duration of starvation (Sibbald, 1976). When collection of excreta from starved cockerels is extended to 48 h, Mutzar & Slinger (1980) and Fisher (1982) suggest that the appropriate correction for EEL may be obtained by multiplying the 24 h losses by 1,85 (or alternatively, the 24 h loss is 0,55 of the EEL after 48 h). The TME of each of the ingredients fed in this trial was calculated using the above correction for EEL (i.e. 46,06 × 1,85 = 82,91 kJ/bird) and these values are given in Table 4.

Whereas AME values differed considerably when calculated on the basis of a 24 h collection period vs 48 h collection, the corresponding TME values did not differ much, except in the case of lucerne meal. In fact, the TME for pollard was higher after a 48 h collection period than after a 24 h period, indicating firstly that pollard probably clears the gut in less than 24 h (confirming the result of Sibbald, 1978) and secondly, that the value assigned to EEL in 48 h is probably inflated. An interesting result is that the TME of fishmeal was not altered by collecting faeces over an additional 24 h period. Sibbald (1978) found that on some occasions feeds like fishmeal and meatmeal were voided within 24 h, whereas at other times periods as long as 52 h were needed. His results with lucerne (alfalfa) were more consistent, this ingredient always requiring more than 24 h to clear the digestive tract. Kessler & Thomas (1980) and J. McNab (personal communication) have consistently found ingredients like fishmeal and lucerne meal to require more than 24 h to clear the digestive tract. Because of the uncertainty in this rate of passage of feed ingredients it is recommended that a 48 h fasting period be used prior to the feeding of the test material, and that a 48 h collection time be used thereafter. This would ensure complete clearance of feeds consumed prior to the balance period, and complete collection of excreta voided as a result of feeding the test material. Because of the variability associated with the results of this and previous reports on the subject of rate of passage of test material, only the TME of lucerne meal has been 'corrected' for delayed retention time in the final AME and TME results presented in Table 7, the corrected value amounting to 0,90 of the original value.

Because of the increasingly large contribution of EEL to the total faecal energy output as the amount of food ingested by the bird is decreased, a greater degree of accuracy in estimating TME should be expected when large amounts of food are offered to the birds. Also, any excreta remaining in the intestine after the collection period has been completed, will contribute less to overall error as food intake is increased. However, Sibbald (1976a) mentioned problems of regurgitation and crop impaction with large intakes of food using his method of TME evaluation and suggested that the amount of food supplied should approximate one percent of the body mass of the birds. In the series of experiments reported here it was found that crop impaction was a real problem when amounts of food in excess of 40 g were fed, especially when fibrous ingredients were used and in spite of their being pelleted.

At very low intakes (5 or 10 g/bird) the error inherent in the estimation of TME is high, as indicated in Table 5,

**Table 4** AME and TME of feed ingredients following different faecal collection times

| Ingredient | ME[1] | 24 h | 36 h | 48 h | % change 24 – 48 h |
|---|---|---|---|---|---|
| Bloodmeal | AME | 16,90 | 15,90 | 15,49 | −8,34 |
| | TME[2] | 18,43 | 18,09 | 18,33 | −0,54 |
| Carcass meal | AME | 14,88 | 13,73 | 13,20 | −11,29 |
| | TME | 16,41 | 15,92 | 16,04 | −2,25 |
| Fishmeal | AME | 14,55 | 13,87 | 13,30 | −8,59 |
| | TME | 16,08 | 16,06 | 16,14 | +0,37 |
| Lucerne meal | AME | 7,04 | 5,54 | 4,91 | −30,26 |
| | TME | 8,58 | 7,73 | 7,75 | −9,67 |
| P.B.P.M. | AME | 17,25 | 16,39 | 15,90 | −7,83 |
| | TME | 18,79 | 18,58 | 18,74 | −0,27 |
| Pollard | AME | 10,86 | 10,54 | 10,21 | −5,99 |
| | TME | 12,38 | 12,73 | 13,05 | +5,41 |

[1] AME and TME expressed as kJ/g.

[2] Endogenous energy loss calculated as being 46,024 kJ/bird in the first 24 h post feeding, decreasing by 0,15 during the second 24 h period (see text).

**Table 5** TME of maize, sunflower and fishmeal as influenced by level of feed input

| Level of feed input (g/bird) | Maize | | Sunflower | | Fishmeal | |
|---|---|---|---|---|---|---|
| | n[1] | TME[2] | n | TME | n | TME |
| 5 | 8 | 17,43 ± 0,92 | 8 | 11,63 ± 1,12 | 7 | 15,85 ± 3,43 |
| 10 | 8 | 15,62 ± 0,75 | 8 | 10,22 ± 1,51 | 8 | 14,78 ± 2,67 |
| 15 | 8 | 14,39 ± 0,29 | 8 | 10,63 ± 0,92 | 8 | 15,21 ± 1,41 |
| 20 | 8 | 14,27 ± 0,34 | 8 | 11,27 ± 0,64 | 8 | 14,25 ± 1,67 |
| 25 | 8 | 14,69 ± 0,30 | 8 | 10,57 ± 0,61 | 8 | 14,74 ± 1,86 |
| 30 | 8 | 14,35 ± 0,53 | 8 | 10,74 ± 0,69 | 8 | 14,37 ± 1,43 |
| 35 | 7 | 14,20 ± 0,54 | 6 | 10,98 ± 0,92 | 8 | 14,29 ± 1,28 |
| 40 | 8 | 14,60 ± 0,44 | 7 | 10,59 ± 1,39 | 8 | 15,25 ± 1,37 |
| 50 | 6 | 14,39 ± 0,50 | 4 | 10,96 ± 1,86 | 7 | 15,19 ± 1,46 |
| 60 | 4 | 14,22 ± 0,86 | 3 | 11,56 ± 1,98 | 8 | 15,93 ± 0,77 |

[1] Number of observations, after discarding data where birds either regurgitated food or had an impacted crop.

[2] TME (kJ/g) determined after 24 h collection period.

where the TME values for maize, sunflower and fishmeal are given at intakes ranging from 5- to 60 g. The high TME values for all three ingredients when 5- and 10 g of food were supplied, compared with values determined when larger amounts were fed, indicate the significant influence of N excretion on energy losses at low intakes. Unfortunately, no estimates of these N losses were made at the time, so the contribution of N to the total energy loss cannot be calculated. These results lend support to the importance of correcting energy losses for N excretion (Fisher, 1982).

The number of birds that regurgitated some or all of the food supplied to them, or that had impacted crops, increased with the amount of food supplied, as can be seen from the number of observations used to calculate the TME results in Table 5. Regurgitation was not a problem at intakes up to 50 g/bird and crop impaction at this level of intake can be prevented by flushing the crop with 50 ml of water a few hours after feeding (J. McNab, personal communication).

Feed intakes considerably in excess of 50 g/bird, can be attained by training birds to consume their daily ration in a one-hour period, and Farrell (1981) quotes intakes as high as 110 g/day when birds are fed in this manner. If birds are to be force-fed, however, the optimum feed allowance would be between 40 and 50 g/bird for a cockerel of about 3000 g in mass, this amount being in excess of the feed allowance suggested by Sibbald (1976a).

The AME value of maize in Table 2 is considerably lower than the corresponding value used by most feed compounders in the U.S.A. and South Africa (13,13 vs 14,43 kJ/g) this being the most significant deviation in the present results from values used by the balanced feed industry in this country. Indeed, the value obtained is almost identical to those quoted by Sibbald (1976b) and J.J. Du Preez (personal communication). To investigate this further, and concurrently to test whether the present method of TME determination can be regarded as yielding additive results, the TME of maize supplemented with either dry egg albumen or with L-lysine HCl was determined.

There was a slight but insignificant improvement in TME as the protein content and amino acid balance of maize was improved (Table 6). When account is taken of the gross energy of egg albumen and its contribution to the energy content of the maize:albumen mixture (assuming a digestibility of 1,00 for albumen), the difference in the TME of maize and the maize:albumen mixture was 0,41 kJ/g (16,26 vs 16,67 kJ/g), this being well within the bounds of error as indicated in Table 6. These results indicate that the gross energy of a feedstuff utilized by an animal is not altered by improving the quantity or quality of the protein in the feedstuff, thus confirming the additive nature of the TME evaluation procedure. The TME of high lysine maize is also no greater than that of standard yellow maize.

As mentioned above, age, body mass and environmental temperature did not significantly influence EEL. The age of the birds varied from 175 d to 469 d, the smallest birds having a body mass of 1 650 g whereas the largest birds measured just in excess of 3 000 g. The lowest temperature recorded in the experimental unit was 8,75°C and the highest was 23,25°C, these values being the arithmetic mean of the maximum and minimum temperatures re-

**Table 6** Effect of increased protein content and improved balance of amino acids on the TME of maize

| Dietary treatment | TME[1] (kJ/g) |
|---|---|
| Maize | 16,26 ± 0,43 |
| Maize + egg albumen (0,90:0,10)[2] | 17,03 ± 0,16 |
| Maize + L-lysine HCl (0,99:0,01) | 16,59 ± 0,45 |
| High lysine maize | 16,56 ± 0,67 |

[1] TME determined by feeding 30 g samples after 24 h fast, faecal collection time being 24 h.

[2] Gross energy of egg albumen determined as 20,36 kJ/g.

corded during the 24 h faecal collection period. A high ($r = 0,44$) correlation existed between body-mass and age, but because the same birds were not used throughout the series of experiments, sufficient variation existed to allow the effects of these two variates to be judged separately.

Of the factors studied, age was found to have the greatest effect on EEL, but this accounted for only 0,084 of the variance. Body mass accounted for 0,068 and this was not improved by using metabolic body size. Environmental temperature accounted for only 0,011 of the variance in EEL, and all three factors combined left 0,849 of the variation unaccounted for. It is reasonable to assume that age, bodymass and environmental temperature do not influence EEL when kept within the ranges used in this experiment.

Of considerably greater concern is the effect of fasting on EEL. In a comprehensive study on this subject Fisher (1982), concluded that the determination of endogenous losses with fasted birds gave results that were too variable and inconsistent. The method recommended by him, and used successfully in his laboratory, is to determine endogenous losses following glucose administration. Glucose is fed during the pre-experimental period (after a 24 h fast) and again at the start of the balance period, using 50 g of glucose each time, the amount in total approximating the energy contained in the test materials. Fisher (1982) used a single value for EEL of 71,5 kJ or 32,5 kJ if corrected for N when a 48 h collection period was used. He suggested that much of the variation in N-loss and in N-corrected energy loss that occurs between experiments, can be associated with the 'condition' of the birds, reflecting age and frequency of use.

Farrell (1981) argued that a common level of EEL cannot be used for all feeds, and to show this, used a relationship between EEL, estimated by regression of energy excretion on intake of different foodstuffs, and the neutral detergent fibre content of the food. Sibbald (1981) has subsequently shown that the above relationship can be explained in terms of differential clearance rates from the intestine, and Fisher (1982) in a very thorough study, concluded that both digestibility of energy (TME) and EEL are constant over a range of intakes from 5- to 70 g, thus validating the TME method of energy evaluation. The TME of maize, sunflower and fishmeal in the present trial, showed a tendency to increase at very low intakes, but, as mentioned previously, this could be expected if no account is taken of the N losses in the excreta. Otherwise the values were remarkably similar throughout the range tested, adding further weight to the views of Sibbald (1981) and Fisher (1982).

During the period in which these experiments were conducted, and subsequently, our views on the determination of TME have changed. A prerequisite for the determination of AME and TME is a valid estimate of endogenous energy loss for birds given the test feeds. We subscribe to the approach of Fisher (1982) where glucose is fed to the birds receiving no test feed both during the fasting period and at the beginning of the balance period. In this way the fasted birds are no more severely depleted of energy than are the birds receiving the test foods. This has the effect of decreasing the EEL and hence the TME. A reasonably accurate measure of AME, comparable to AME values used currently, can then be obtained by subtracting the EEL divided by 80 from the TME value. This value, termed AME(80), indicates the AME that would result from a balance study in which 80 g of feed was fed. Although no correction for N-loss was made in any of the trials reported here, evidence suggests that this is most important (Minnaar & Erasmus, 1981; Fisher, 1982). A N-correction of 17,88 kJ/bird was therefore used in calculating the $TME_n$ and $AME_n(80)$ content of the feedstuffs assayed in the first series of experiments and these values are presented in Table 7.

**Table 7** 'Corrected' AME and TME values of food ingredients

| Ingredient | $AME_n(80)^1$ | $TME_n^2$ |
|---|---|---|
| Bloodmeal | 14,87 | 15,09 |
| Brewers grain | 10,80 | 11,01 |
| Carcass meal | 14,14 | 14,36 |
| Fishmeal | 13,60 | 13,83 |
| Groudnut oilcake | 10,53 | 10,75 |
| Lucerne meal$^3$ | 5,70 | 5,92 |
| Maize | 13,60 | 13,82 |
| P.B.P.M. | 15,60 | 15,81 |
| Ricebran | 12,80 | 13,01 |
| Sorghum | 12,84 | 13,07 |
| Sunflower oilcake | 8,95 | 9,17 |
| Wheat bran | 8,60 | 8,81 |
| Wheat pollard | 9,60 | 9,82 |

[1] Corrected to an intake of 80 g/d with N correction.

[2] Corrected to an EEL, with N correction, of 17,88 kJ/bird d.

[3] Corrected for delayed retention time.

In the experiments and discussions reported here, we believe that there is a basis for an improved methodological approach to the determination of the TME and AME of feeds, and in the light of work by Sibbald (1981), Fisher (1982) and McNab (Personal communication) we would recommend the following modifications to the original method outlined by Sibbald (1976a):

(i) A 48 h pre-experimental period and a 48 h experimental (collection) period.

(ii) 50 g glucose should be fed to all birds 24 h after the fasting period has commenced. It is assumed that this glucose will be fully digested and utilized.

(iii) A 50 g sample of feed should be supplied, followed a few hours later by 50 ml water.

(iv) Correction should be applied to N content of excreta.

(v) EEL to be determined with birds fed 50 g glucose 24 h after the start of the 48 h fasting period and at the start of the balance period. Correction to be applied to energy voided as N in the excreta.

(vi) $AME_n(80)$ should be determined from the $TME_n$ value and used for comparative purposes.

(vii) Birds should not be used more frequently than once every 3 weeks.

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