# THE NATURE AND DETERMINATION OF METABOLIZABLE ENERGY

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## ABSTRACT

Part 1 of this thesis involves a review along quantitative lines of investigations concerning metabolizable energy (ME) in poultry nutrition. A model for the mechanism of nitrogen (N) excretion is presented and examined in an experimental section comprising Part 2.

In Part 1, Chapter 1 is an exposition of the distribution and utilization of feed energy and raises the subject of additivity and questions of standardization of ME assay procedure. Chapter 2 consists of 2 sections. Section 1 provides a literature review of the bioassay determination of apparent metabolizable energy (AME). It covers an analysis of the nature of AME and explains basic concepts, provides mathematical definitions and perspectives and N corrected AME values ($AME_n$) are discussed. Further it describes methods of determination and provides an examination of the factors involved in AME variation. Section 2 deals with the nature of true metabolizable energy (TME) in which definitions and derivations of TME are provided, the relationship between TME and AME given, deviations from linearity of the energy excreted (EO) on energy input (EI) regression investigated and N corrected TME values ($TME_n$) discussed. Additionally, methods and evidence bearing on the central premise to TME are presented and other areas that have gained attention reviewed.

In Part 2, the subject of Chapter 3 is a linear experimental model developed by King (1984) to explain deviations in linearity of the relationship between N excreted (NO) and N intake (NI) as it may apply to adult cockerels and the nature of the correction of TME values to zero N balance (ZNB). Chapter 4 deals with 2 experiments, LN 202 and LN 204. The primary objective of Experiment LN 202 was to examine and investigate the regression relationship, EO on EI obtained for adult cockerels, and to assess the effect on it of correcting EO to ZNB. Experiment LN 204 was set up to study the impact of diet and assay procedure on TME of meat and bone meal (M & B) and to examine the effect on these values of correcting to ZNB. The effect of assay procedure on TME and $TME_n$ of a whole diet was also explored.

In Experiment LN 202 2 slopes were obtained for the regression relationship, EO on EI, and on correcting EO to ZNB 1 slope satisfactorily represented the relationship. This was consistent with expectations arising from the model. The model suggests that this slope contains a bias element that causes TME values to deviate from unbiassed TME.

In Experiment LN 204 the TME values of M & B as determined by dietary inclusion and by direct supply were compared and assessed in terms of the model. Correction of the TMEs to ZNB resulted in a single value. TME assessment of a whole diet by 2 different assays resulted in similar values when the values, according to the model, estimated the same quantity and different values when the quantities measured were, as predicted by the model, different. Correction to ZNB caused like values to deviate and unlike values to come closer together.

Chapter 5 provides an overview of the model and the experimental findings and outlines the conclusions that have been drawn from this work.

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| | |
|---|---|
| $a_N$ | The intercept on Y of the slope for N excretion on N input. |
| ADE | Apparent digestible energy. |
| AME | Apparent metabolizable energy. |
| $a_{Nm}$ | Nitrogen excretion constant arising from day to day wasting of N from the body. It is the result of normal maintenance activity. It is body weight related and independent of the food fed. |
| $a_{Np}$ | Nitrogen excreted resulting from tissue protein catabolism that takes place for the purpose of supplying energy needs and takes place during starvation. |
| $AME_b$ | AME obtained by bioassay. |
| $AME_c$ | The conceptual measure of AME. |
| $AME_n$ | Nitrogen corrected AME (commonly to zero N balance). |
| $AME_{(n)}$ | Refers to AME or $AME_n$. |
| b | The slope for the subscript by which it is defined. |
| $b_{Nr}$ | The N excreted per unit of N input over subsequent values of N input. |
| $b_{Nna}$ | The proportion of N input that is not metabolized and is eliminated directly. |
| BE | Bioavailable energy. |
| BM | Basal metabolism. |
| BW | Body weight. |
| BMR | The standard or basal metabolic rate. |
| C.L. | Confidence limits. |
| $Cr_2O_3$ | Chromic oxide. |
| DE | Digestible energy. |
| E | Energy. |
| EE | Refer to text for specific meaning:<br>(i) Excreta energy.<br>(ii) Endogenous energy. |
| $EE_n$ | Energy excreted (by control birds) corrected for energy equivalent zero N balance. |
| EI | Energy input. |
| EO | Energy excreted. |
| $EO_n$ | Energy excreted (by fed birds) corrected for energy equivalent zero N balance. |

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|---|---|
| $E_{NB}$ | Energy equivalent of N balance. |
| $EO_s$ | Energy excreted over subsequent values of food intake. |
| $Ea_{Nm}$ | The intercept of the energy of N excreted arising from normal maintenance activity. |
| $Ea_{Np}$ | The intercept of the energy of N excreted arising from tissue protein breakdown during starvation. |
| FE | Faecal energy. |
| Fi | Weight of food residues. |
| FeE | The energy of microflora and microbial debris voided as faeces. |
| FeN | The N content of microflora and microbial debris voided as faeces. |
| FfE | The energy of food residues passaged through the gut. |
| FfN | The N content of food residues passaged through the gut. |
| FiE | The energy of food residues. |
| $F_{ir}$ | Weight of excreta of food residues remaining which are eliminated via the gut or the urine. |
| FmE | Energy of products of the gut specified as cells of the gut wall, bile mucous and unabsorbed digestible juices and gas. |
| FmN | The N content of the gut specified as cells of the gut wall, bile mucous and unabsorbed digestible juices and gas. |
| FMR | Fasting metabolic rate. |
| FuE | The energy of materials absorbed across the intestine and excreted directly in the urine without undergoing metabolic change. |
| FuN | The N content of materials absorbed across the intestine and excreted directly in the urine without undergoing metabolic change. |
| $F_{ign}$ | Weight of N containing products of the food not absorbed and passaged via the gut. |
| $F_{iun}$ | Weight of N products that are absorbed across the gut wall and excreted directly in the urine without undergoing metabolic change. |
| $F_{ir}E$ | Energy of excreta of food residues remaining which are eliminated via the gut or the urine. |
| $F_{ign}E$ | Energy of N containing products of the food not absorbed and passaged via the gut. |

| | |
|---|---|
| $F_{iun}E$ | Energy of N products that are absorbed across the gut wall and excreted directly in the urine without undergoing metabolic change. |
| Fm+eE | FmE + FeE. |
| GE | Gross energy. |
| GEa | The sum of energy not lost as energy of N excretion products in the urine resulting from metabolism of food absorbed, GEr, and that eliminated by the process UiE. |
| GEr | Energy not lost as energy of N excretion products in the urine resulting from metabolism of food absorbed. |
| HI | Heat increment. |
| HP | The total heat production of an animal consuming food in a thermally neutral environment. |
| HBC | Heat to keep body cold. |
| HBW | Heat to keep body warm. |
| LCT | Lower critical temperature. |
| ME | Metabolizable energy. |
| M & B | Meat and bone meal. |
| N | Nitrogen. |
| NB | Nitrogen balance. |
| NI | Nitrogen input. |
| NO | Nitrogen excreted. |
| $NE_m$ | Maintenance energy. |
| $NE_p$ | Production energy. |
| $NE_w$ | Energy of work. |
| $NO_i$ | Nitrogen excreted over initial values of N fed or input. |
| $NO_s$ | Nitrogen excreted over subsequent values of N fed or input. |
| $NI_{ge}$ | Nitrogen input per unit of food over gross energy input per unit of food. |
| $NE_{m+p}$ | Net energy for body maintenance and for production purposes. |
| PRC | Poultry Research Centre. |
| $r^2$ | Correlation. |
| S | Standard deviation. |
| S.E. | Standard error of the mean. |
| TME | True metabolizable energy. |
| $TME_b$ | Biassed TME values. |

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|---|---|
| $TME_h$ | TME obtained over high food intake levels (equivalent to $TME_s$). |
| $TME_L$ | TME at level of energy intake stated, e.g. $TME_{L3}$ = TME at level 3. |
| $TME_l$ | TME obtained over low food intake levels (equivalent to $TME_{in}$). |
| $TME_n$ | TME corrected to zero N balance. |
| $TME_o$ | Biassed TME values. |
| $TME_s$ | TME for subsequent values of food intake or as obtained from the subsequent slope (equivalent to $TME_h$). |
| $TME_u$ | Unbiassed TME values. |
| $TME_{in}$ | TME for initial values of food intake or as obtained from the initial slope (equivalent to $TME_l$). |
| $TME_{Ni}$ | TME corrected for N over initial values of food intake. |
| $TME_{Ns}$ | TME corrected for N over subsequent values of food intake. |
| $TME_{ZNB}$ | TME corrected to zero N balance. |
| $TME_{N_{UmE}}$ | TME corrected for energy of N arising from UmE. |
| $TME_{N_{UmE+UeE}}$ | TME corrected for energy of N arising from both UmE and UeE. |
| UE | Urinary energy. |
| UCT | Upper critical temperature. |
| UeE | Energy equivalent of N by-products in the urine resulting from the day to day wasting of N due to maintenance activity. |
| UeN | The N content of by-products in the urine resulting from the day to day wasting of N due to maintenance activity. |
| UiE | The energy of N excretion products in the urine resulting from metabolic breakdown of absorbed food. |
| UmE | Energy equivalent of N by-products in the urine resulting from tissue catabolism and evident under starvation conditions. |
| UmN | The N content of by-products in the urine resulting from tissue catabolism and evident under starvation conditions. |
| VAE | Energy of voluntary activity or activity increment. |
| ZNB | Zero N balance. |
| ZNR | Zero N retention. |
| $\Delta$ | Change in. |