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THE NATURE AND DETERMINATION OF
METABOLIZABLE ENERGY

A THESIS PRESENTED FOR THE PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF AGRICULTURAL SCIENCE IN ANIMAL SCIENCE
AT
MASSEY UNIVERSITY
PALMERSTON NORTH, NEW ZEALAND

POI KUNG SIM

1986
Title of thesis: THE NATURE AND DETERMINATION OF METABOLIZABLE ENERGY

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ACKNOWLEDGEMENTS

I am deeply indebted to my supervisor, Mr R.D. King, the Senior Research Officer of the Poultry Research Centre (PRC), Massey University, for his guidance, patience, encouragement and valuable help throughout the course of this study.

Grateful acknowledgement is made to Mr M.R. Patchell, the Director of the PRC and Dr D.C. Johns, the Research Officer of the PRC for their helpful advice and support.

Special thanks are due to Mr G.D. Watts, PRC, for his help with the determination of gross energy and Mr S.H. Voon, PRC, for his technical assistance in the laboratory. The co-operation and assistance in the experiments provided by the farm staffs of the PRC are also greatly appreciated.

I wish to extend thanks to all my friends who assisted in one way or another. Finally, very special mention to my family for their support and patience during my endeavours in New Zealand.
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 (AMEn) 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\textsubscript{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\textsubscript{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 unbiased 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.
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>i</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>ix</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xi</td>
</tr>
</tbody>
</table>

### PART 1

#### CHAPTER 1 INTRODUCTION

1.1 Faecal Energy                               | 8    |
1.2 Digestible Energy                           | 8    |
1.3 Urinary Energy                              | 8    |
1.4 Metabolizable Energy                        | 8    |
1.5 Heat Increment                              | 9    |
1.6 Net Energy                                  | 10   |
1.7 Maintenance Energy                          | 10   |
  1.7.1 Basal Metabolism                         | 10   |
  1.7.2 Energy of Voluntary Activity            | 12   |
  1.7.3 Heat to Keep Body Warm                  | 12   |
  1.7.4 Heat to Keep Body Cold                  | 12   |
1.8 Production Energy                           | 13   |

#### CHAPTER 2 METABOLIZABLE ENERGY

2.1 The Nature of Apparent Metabolizable Energy | 15   |
  2.1.1 Point Perspective                       | 17   |
  2.1.2 Linear Perspective                      | 20   |
  2.1.3 Nitrogen Corrected Apparent Metabolizable Energy (AME<sub>n</sub>) | 25   |
2.2 Chemical Determination of AME               | 30   |
2.3 Methods of Determination of Apparent Metabolizable Energy | 32   |
  2.3.1 Conventional Methods                    | 35   |
    2.3.1 (a) The Assay of Hill et al. (1960) and Potter et al. (1960) | 35   |
    2.3.1 (b) The Assay of Sibbald and Slinger (1963a) | 38   |
    2.3.1 (c) Assay Variations                   | 40   |
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3.2</td>
<td>Rapid Method</td>
<td>41</td>
</tr>
<tr>
<td>2.3.2 (a)</td>
<td>The Assay of Farrell (1978b)</td>
<td>41</td>
</tr>
<tr>
<td>2.3.2 (b)</td>
<td>The Assay of Sibbald (1975)</td>
<td>41</td>
</tr>
<tr>
<td>2.4</td>
<td>Factors Affecting AME(n) Values</td>
<td>42</td>
</tr>
<tr>
<td>2.4.1</td>
<td>Nitrogen Retention</td>
<td>42</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Quantitative Evaluation of Excreta Elimination</td>
<td>43</td>
</tr>
<tr>
<td>2.4.3</td>
<td>Level of Food Intake</td>
<td>43</td>
</tr>
<tr>
<td>2.4.4</td>
<td>Substitution Effects</td>
<td>46</td>
</tr>
<tr>
<td>2.4.5</td>
<td>Effect of Basal Diets</td>
<td>46</td>
</tr>
<tr>
<td>2.4.6</td>
<td>Effect of Nutrient Imbalances and Deficiencies</td>
<td>47</td>
</tr>
<tr>
<td>2.4.7</td>
<td>Species</td>
<td>47</td>
</tr>
<tr>
<td>2.4.8</td>
<td>Strains</td>
<td>48</td>
</tr>
<tr>
<td>2.4.9</td>
<td>Age</td>
<td>48</td>
</tr>
<tr>
<td>2.4.10</td>
<td>Environmental Temperatures</td>
<td>49</td>
</tr>
<tr>
<td>2.4.11</td>
<td>Stocking Density and Colony Size</td>
<td>49</td>
</tr>
<tr>
<td>2.4.12</td>
<td>Method of Calculation</td>
<td>50</td>
</tr>
<tr>
<td>2.4.13</td>
<td>Pelleting Effects</td>
<td>50</td>
</tr>
<tr>
<td>2.4.14</td>
<td>Laboratory Handling</td>
<td>50</td>
</tr>
<tr>
<td>2.4.15</td>
<td>Fats</td>
<td>51</td>
</tr>
</tbody>
</table>

SECTION 2 TRUE METABOLIZABLE ENERGY | 52

2.5 The Nature of True Metabolizable Energy | 53

2.5.1 Definitions and Derivations | 53

2.5.2 The Relationship between TME and AME | 59

2.5.3 Deviation from Linearity | 60

2.5.4 Nitrogen Corrected True Metabolizable Energy (TMEₙ) | 62

2.6 The True Metabolizable Energy Bioassay | 66

2.6.1 The Assay of Sibbald (1976a) | 66

2.6.2 Assay Variations | 70

2.7 Evidence Related to the Central Premise of TME | 72

2.8 Additivity and Reproducibility | 74
PART 2

CHAPTER 3  A THEORETICAL STUDY OF THE RELATIONSHIP BETWEEN NITROGEN EXCRETION AND TRUE METABOLIZABLE ENERGY  75
3.1 A Model of Nitrogen Balance and Its Relationship to TME .......... 77
   3.1.1 Analysis of the Excreta Energy Slope of TME ............... 77
   3.1.2 A Model of Nitrogen Balance .................................. 80
   3.1.3 Correction of TME for UmE and for UmE + UeE .......... 86
   3.1.4 Correction of TME to Zero Nitrogen Balance ........... 89

CHAPTER 4  EXPERIMENTAL  93
4.1 Experiment 1 -- LN 202 .................................................. 98
   4.1.1 Objectives ............................................................ 98
   4.1.2 Materials, Methods and Treatments .......................... 98
   4.1.3 Results ............................................................... 103
   4.1.4 Discussion ......................................................... 118
4.2 Experiment 2 -- LN 204 .................................................. 121
   4.2.1 Objectives ............................................................ 121
   4.2.2 Materials, Methods and Treatments .......................... 121
   4.2.3 Results ............................................................... 125
   4.2.4 Discussion ......................................................... 133

CHAPTER 5  SUMMARY AND CONCLUSIONS  136

BIBLIOGRAPHY ............................................................... 141
APPENDIX

Table

A1 Experiment LN 202: Individual bird body weights at the assay start and at 24 hour intervals ........................................ 165

A2 Experiment LN 202: Individual bird food intake for days of the assay ................................................................. 166

A3 Experiment LN 202: Nitrogen of excreta per bird day (g) and nitrogen of excreta per kg$^{0.67}$ BW per bird day (mg) .......... 167

A4 Experiment LN 202: Air dry excreta output per bird per day .... 168

A5 Constraints used in Experiment LN 202 diet ..................... 169

A6 Ingredient, calculated and determined nutrient composition of Experiment LN 202 diet ................................................. 170

A7 Ingredient composition of Experiment LN 204 diets .............. 171

A8 Calculated and determined nutrient composition of Experiment LN 204 diets .......................................................... 172

A9 Ingredient and calculated nutrient composition of the "low density" maintenance diet used before and between experiments .................................................. 173

A10 Analysis of variance tables for estimating proportional contribution of components of the total variance of nitrogen excreted in mg per kg BW per day ........................................ 174

A11 Sums of squares of regression determinations associated with data of Table 4.8 ......................................................... 176
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 The partition of gross energy of food (Vohra, 1972)</td>
<td>2</td>
</tr>
<tr>
<td>2.1 Relationship between apparent metabolizable energy value and food intake (Guillaume and Summers, 1970)</td>
<td>44</td>
</tr>
<tr>
<td>2.2 Theoretical relationships among apparent (AME) and true (TME) metabolizable energy and their nitrogen-corrected equivalents (AMEn, TMEn) for various intake levels of a single feedingstuff (Wolynetz and Sibbald, 1984)</td>
<td>45</td>
</tr>
<tr>
<td>3.1 Slope components of energy excretion (King, 1984)</td>
<td>78</td>
</tr>
<tr>
<td>3.2 Relationships between nitrogen input, nitrogen excreted and zero nitrogen balance (King, 1984)</td>
<td>81</td>
</tr>
<tr>
<td>4.1 Components of excreta energy</td>
<td>94</td>
</tr>
<tr>
<td>4.2 The relationship between endogenous excreta energy and levels of energy fed on TME</td>
<td>95</td>
</tr>
<tr>
<td>4.3 The effect on TME of correcting to zero nitrogen balance</td>
<td>97</td>
</tr>
<tr>
<td>4.4 Treatment 24 hour nitrogen excreted per kg(^{0.67}) BW associated with each day's feeding schedule</td>
<td>107</td>
</tr>
<tr>
<td>4.5 The relationship between nitrogen input and nitrogen excreted</td>
<td>109</td>
</tr>
<tr>
<td>4.6 Relationship between nitrogen input and nitrogen balance (upper line) and between TME input and energy retention (lower line)</td>
<td>110</td>
</tr>
<tr>
<td>4.7 Regression relationships for energy excreted on energy input, nitrogen balance x 36.51 kJ on energy input and energy excreted corrected for nitrogen balance x 36.51 kJ on energy input</td>
<td>114</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Calculated and determined TME values of whole diets (Edmundson et al., 1978; Edmundson, 1979 and Edmundson, 1981)</td>
<td>5</td>
</tr>
<tr>
<td>4.1 The body weight allocations to treatment for Experiment LN 202</td>
<td>100</td>
</tr>
<tr>
<td>4.2 Timetable of assay procedures for Experiment LN 202</td>
<td>101</td>
</tr>
<tr>
<td>4.3 Treatment mean body weights by days</td>
<td>104</td>
</tr>
<tr>
<td>4.4 Treatment mean food intakes by days</td>
<td>104</td>
</tr>
<tr>
<td>4.5 Treatment mean dietary nitrogen intake (g/b/d)</td>
<td>105</td>
</tr>
<tr>
<td>4.6 Treatment mean excreta nitrogen (g/b/d)</td>
<td>105</td>
</tr>
<tr>
<td>4.7 Gross energy of air dry excreta based on samples weighted for days (kJ/b/d)</td>
<td>106</td>
</tr>
<tr>
<td>4.8 Summary of regression determinations and ( \text{TME/TME}_n ) estimations</td>
<td>113</td>
</tr>
<tr>
<td>4.9 The slopes obtained by regressions of energy excreted on energy input (uncorrected), energy equivalent nitrogen balance on energy input and energy excreted corrected for energy equivalent nitrogen balance on energy input (corrected) for various combination of treatments</td>
<td>117</td>
</tr>
<tr>
<td>4.10 Timetable of assay procedures for Experiment LN 204</td>
<td>123</td>
</tr>
<tr>
<td>4.11 Analyzed nitrogen and gross energy of treatment diets of LN 202 and LN 204</td>
<td>126</td>
</tr>
</tbody>
</table>
4.12 Meat and bone meal -- by basal -- regression relationships ... 127

4.13 Meat and bone meal -- force feeding -- regression relationships .................................................. 128

4.14 LN 202 diet -- force feeding -- regression relationships .... 129

4.15 Food intake, energy, nitrogen and nitrogen balance data means over final 3 days of Treatments F, D and E meat and bone meal......................................................... 130

4.16 Energy, nitrogen and energy equivalent nitrogen balance data of Treatments A, B and C meat and bone meal.................. 131

4.17 Energy, nitrogen and energy equivalent nitrogen balance data of Treatments A, B and C LN 202 diet ......................... 132

4.18 TME measurements of meat and bone meal and diet LN 202 ...... 134
LIST OF ABBREVIATIONS

\( a_N \) 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:

(i) Excreta energy.

(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.
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{NB}$</td>
<td>Energy equivalent of N balance.</td>
</tr>
<tr>
<td>$E_{O_s}$</td>
<td>Energy excreted over subsequent values of food intake.</td>
</tr>
<tr>
<td>$E_{ANm}$</td>
<td>The intercept of the energy of N excreted arising from normal maintenance activity.</td>
</tr>
<tr>
<td>$E_{ANp}$</td>
<td>The intercept of the energy of N excreted arising from tissue protein breakdown during starvation.</td>
</tr>
<tr>
<td>$FE$</td>
<td>Faecal energy.</td>
</tr>
<tr>
<td>$Fi$</td>
<td>Weight of food residues.</td>
</tr>
<tr>
<td>$FeE$</td>
<td>The energy of microflora and microbial debris voided as faeces.</td>
</tr>
<tr>
<td>$FeN$</td>
<td>The N content of microflora and microbial debris voided as faeces.</td>
</tr>
<tr>
<td>$FfE$</td>
<td>The energy of food residues passed through the gut.</td>
</tr>
<tr>
<td>$FfN$</td>
<td>The N content of food residues passed through the gut.</td>
</tr>
<tr>
<td>$FiE$</td>
<td>The energy of food residues.</td>
</tr>
<tr>
<td>$Fir$</td>
<td>Weight of excreta of food residues remaining which are eliminated via the gut or the urine.</td>
</tr>
<tr>
<td>$FmE$</td>
<td>Energy of products of the gut specified as cells of the gut wall, bile mucous and unabsorbed digestible juices and gas.</td>
</tr>
<tr>
<td>$FmN$</td>
<td>The N content of the gut specified as cells of the gut wall, bile mucous and unabsorbed digestible juices and gas.</td>
</tr>
<tr>
<td>$FMR$</td>
<td>Fasting metabolic rate.</td>
</tr>
<tr>
<td>$FuE$</td>
<td>The energy of materials absorbed across the intestine and excreted directly in the urine without undergoing metabolic change.</td>
</tr>
<tr>
<td>$FuN$</td>
<td>The N content of materials absorbed across the intestine and excreted directly in the urine without undergoing metabolic change.</td>
</tr>
<tr>
<td>$F_{ign}$</td>
<td>Weight of N containing products of the food not absorbed and passaged via the gut.</td>
</tr>
<tr>
<td>$Fi_{un}$</td>
<td>Weight of N products that are absorbed across the gut wall and excreted directly in the urine without undergoing metabolic change.</td>
</tr>
<tr>
<td>$F_{irE}$</td>
<td>Energy of excreta of food residues remaining which are eliminated via the gut or the urine.</td>
</tr>
<tr>
<td>$F_{ignE}$</td>
<td>Energy of N containing products of the food not absorbed and passaged via the gut.</td>
</tr>
</tbody>
</table>
Energy of N products that are absorbed across the gut wall and excreted directly in the urine without undergoing metabolic change.

FmE + FeE.

Gross energy.

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.

Energy not lost as energy of N excretion products in the urine resulting from metabolism of food absorbed.

Heat increment.

The total heat production of an animal consuming food in a thermally neutral environment.

Heat to keep body cold.

Heat to keep body warm.

Lower critical temperature.

Metabolizable energy.

Meat and bone meal.

Nitrogen.

Nitrogen balance.

Nitrogen input.

Nitrogen excreted.

Maintenance energy.

Production energy.

Energy of work.

Nitrogen excreted over initial values of N fed or input.

Nitrogen excreted over subsequent values of N fed or input.

Nitrogen input per unit of food over gross energy input per unit of food.

Net energy for body maintenance and for production purposes.

Poultry Research Centre.

Correlation.

Standard deviation.

Standard error of the mean.

True metabolizable energy.

Biassed TME values.
TME\textsubscript{h} \quad \text{TME} \text{ obtained over high food intake levels (equivalent to TME\textsubscript{s}).}

TME\textsubscript{L} \quad \text{TME at level of energy intake stated, e.g. TME\textsubscript{L3} = \text{TME at level 3.}}

TME\textsubscript{1} \quad \text{TME obtained over low food intake levels (equivalent to TME\textsubscript{in}).}

TME\textsubscript{c} \quad \text{TME corrected to zero \textit{N} balance.}

TME\textsubscript{O} \quad \text{Biassed \text{TME} values.}

TME\textsubscript{S} \quad \text{TME for subsequent values of food intake or as obtained from the subsequent slope (equivalent to TME\textsubscript{R}).}

TME\textsubscript{U} \quad \text{Unbiassed \text{TME} values.}

TME\textsubscript{in} \quad \text{TME for initial values of food intake or as obtained from the initial slope (equivalent to TME\textsubscript{1}).}

TME\textsubscript{Ni} \quad \text{TME corrected for \textit{N} over initial values of food intake.}

TME\textsubscript{Ns} \quad \text{TME corrected for \textit{N} over subsequent values of food intake.}

TME\textsubscript{NB} \quad \text{TME corrected to zero \textit{N} balance.}

TME\textsubscript{UmE} \quad \text{TME corrected for energy of \textit{N} arising from UmE.}

TME\textsubscript{UUmE+UeE} \quad \text{TME corrected for energy of \textit{N} arising from both UmE and UeE.}

UE \quad \text{Urinary energy.}

UCT \quad \text{Upper critical temperature.}

UeE \quad \text{Energy equivalent of \textit{N} by-products in the urine resulting from the day to day wasting of \textit{N} due to maintenance activity.}

UeN \quad \text{The \textit{N} content of by-products in the urine resulting from the day to day wasting of \textit{N} due to maintenance activity.}

UIE \quad \text{The energy of \textit{N} excretion products in the urine resulting from metabolic breakdown of absorbed food.}

UmE \quad \text{Energy equivalent of \textit{N} by-products in the urine resulting from tissue catabolism and evident under starvation conditions.}

UmN \quad \text{The \textit{N} content of by-products in the urine resulting from tissue catabolism and evident under starvation conditions.}

VAE \quad \text{Energy of voluntary activity or activity increment.}

ZNB \quad \text{Zero \textit{N} balance.}

ZNR \quad \text{Zero \textit{N} retention.}

\Delta \quad \text{Change in.}