



**UNIVERSITI PUTRA MALAYSIA**

**SYSTEMS APPROACH TO EVALUATE GROWTH AND  
MEAT PRODUCTION OF SHEEP UNDER  
TWO PRODUCTION SYSTEMS**

**CHAIYAWAN WATTANACHANT**

**FPV 1999 1**

**SYSTEMS APPROACH TO EVALUATE GROWTH AND  
MEAT PRODUCTION OF SHEEP UNDER  
TWO PRODUCTION SYSTEMS**

**CHAIYAWAN WATTANACHANT**

**DOCTOR OF PHILOSOPHY  
UNIVERSITI PUTRA MALAYSIA**

**1999**



**SYSTEMS APPROACH TO EVALUATE GROWTH AND  
MEAT PRODUCTION OF SHEEP UNDER  
TWO PRODUCTION SYSTEMS**

**By**

**CHAIYAWAN WATTANACHANT**

**Dissertation Submitted in Fulfilment of the Requirement for  
the Degree of Doctor of Philosophy in the Faculty of  
Veterinary Medicine and Animal Science,  
Universiti Putra Malaysia**

**May 1999**



**Dedicated to**

**My father, Chaiyong Wattanachant  
and my mother, Wannee Wattanachant  
for their understanding and encouragement  
which have been a great constant source of inspiration**



## ACKNOWLEDGEMENTS

I would like to express my appreciation and sincere gratitude to my supervisor, Professor Dr. Dahlan bin Ismail for his invaluable guidance, suggestions, constructive criticisms and constant encouragement throughout the course of study and in the preparation of this dissertation. My deep appreciation and gratitude also go to Associate Professor Dr. Mohamed Ali Rajion and Associate Professor Dr. Abdul Razak Alimon, members of my supervisory committee for their invaluable guidance and suggestions, constructive criticisms and encouragement.

I wish to thank Mr. Mohamed Azri bin Haji Hamzah, the former senior manager of Planning and Development Division, Far East Holdings Berhad for his approval to use the sheep flock for this research. I also would like to thank Dr. Zulkifli bin Abdullah, former Manager of Sheep Unit and the Manager of Cempakal Plantation, Far East Holdings Berhad, for his kind support and encouragement. Special thanks to all the staff at Sungai Seraya Plantation for their kind help and assistance in data collection.

I would like to thank the Director of the Department of Veterinary Services, Pahang and Dr. Zainor bin Hj.Mohd, Department of Veterinary Services, Pahang for their kind support in providing transport.



I would like to thank the Department of Animal Science, UPM for providing the research facilities. I wish to thank Professor Dato' Dr. Mohd. Mahyuddin bin Mohd. Dahan for his kind suggestion of this Thesis. Thanks are also due to Mr. Shahril Hassan, Mr. Shukri Jusoh, Mr. Bakeri bin Abd. Rahman, Mr. Ibrahim bin Mohsin and Mr. Saparin bin Demin, the technical staff from Department of Animal Science, UPM and Mr. Johari bin Rapin, Department of Biomedical Science, UPM for his technical support.

I am grateful to the Southeast Asian Regional Centre for Graduate Study and Research in Agriculture (SEARCA) for providing me the scholarship to enable me to complete my study.

Appreciation also goes to Khon Kaen University, Ministry of University Affairs, Kingdom of Thailand for permitting me to take the study leave.

Last but not the least, I am greatly indebted to my father, Mr. Chaiyong Wattanachant, for his great loving support. I wish to express my deepest appreciation to my wife, Mrs. Saowakon Wattanachant, for her encouragement. Special thanks to Mr. Ng Kok Hong, Mr. Isalahuddin bin Musa and Dr. Goh Yong Meng who kindly offered help and encouragement during my study. Finally, I also would like to thank all my friends who gave me encouragement and support during the period of my study at UPM.



## TABLE OF CONTENTS

|   | <b>Page</b> |
|---|-------------|
| <b>ACKNOWLEDGEMENTS</b> .....   | iii         |
| <b>LIST OF TABLES</b> .....   | xi          |
| <b>LIST OF FIGURES</b> .....  | xvii        |
| <b>LIST OF PLATES</b> .....   | xix         |
| <b>LIST OF ABBREVIATION</b> .....   | xx          |
| <b>ABSTRACT</b> .....   | xxiii       |
| <b>ABSTRAK</b> .....  | xxvii       |
| <b>CHAPTER</b>  |             |
| <b>I INTRODUCTION</b> .....   | 1           |
| <b>II LITERATURE REVIEW</b> .....   | 5           |
| Background of Modelling and Simulation in Animal<br>Production Systems..... | 5           |
| Terminology.....  | 6           |
| Modelling and Simulation in Animal Production Systems.....                  | 13          |
| Modelling and Simulation in Sheep Production systems.....                   | 17          |
| Growth of an Animal and Its Model.....                                      | 22          |
| The Allometric Model.....   | 25          |
| The Brody (or Monomolecular) Model.....                                     | 26          |
| The Bertalanffy Model.....  | 27          |
| The Gompertz Model.....   | 27          |
| The Logistic Model.....   | 29          |
| The Richards Model.....   | 29          |
| Modelling in Meat Production.....   | 32          |
| Factors which Influence Growth and Body<br>Composition of Animal.....       | 34          |
| Age.....  | 34          |
| Weight.....   | 35          |
| Breed.....  | 35          |
| Sex.....  | 36          |
| Hormones.....   | 38          |
| Nutrition.....  | 39          |
| Environment.....  | 40          |
| Sheep Production System in the Tropics.....                                 | 42          |
| Extensive System.....   | 42          |
| Intensive System.....   | 43          |
| Semi-Intensive System.....  | 43          |



|            |   |           |
|------------|---|-----------|
|            | Sheep-Tree Crop Integration System.....                                     | 44        |
| <b>III</b> | <b>CONCEPTUAL MODELS AND GENERAL APPROACH OF THE STUDY.....</b>             | <b>45</b> |
|            | The Development of Conceptual Model of the Study.....                       | 45        |
|            | The Conceptual Model of Sheep Integrated in Oil Palm Plantation.....        | 45        |
|            | The Conceptual Model of Sheep in Feedlot System.....                        | 48        |
|            | Analytical Background of Energy Utilisation.....                            | 48        |
|            | Metabolisable Energy.....   | 51        |
|            | Net Energy Requirements.....  | 54        |
|            | Computer Simulation.....  | 55        |
| <b>IV</b>  | <b>EXPERIMENTAL PROCEDURE.....</b>  | <b>58</b> |
|            | Locations of Experiment.....  | 58        |
|            | Animal Breeds.....  | 58        |
|            | Animal Management.....  | 59        |
|            | Experiment 1: Integration System.....                                       | 59        |
|            | Experiment 2: Feedlot System.....   | 60        |
|            | Slaughter Technique.....  | 61        |
|            | Dissection Technique.....   | 62        |
|            | Laboratory Chemical Analysis Methods.....                                   | 62        |
|            | Dry Matter.....   | 62        |
|            | Ash.....  | 63        |
|            | Crude Protein.....  | 63        |
|            | Ether Extraction.....   | 64        |
|            | Crude Fibre.....  | 65        |
|            | Acid Detergent Fibre.....   | 66        |
|            | Determination of the Metabolisable Energy.....                              | 66        |
|            | Determination of Chromium.....  | 67        |
|            | Preparation of the Reagents.....  | 67        |
|            | Preparation of the Standards.....   | 67        |
|            | Chromium Analysis.....  | 68        |
|            | Determination of Dry Matter Digestibility Using Pepsin-Cellulase Assay..... | 68        |
|            | Cellulase Solution.....   | 68        |
|            | Analysis of Dry Matter Digestibility.....                                   | 69        |
|            | Measurement.....  | 69        |
|            | Live Weight Measurements.....   | 69        |
|            | Carcass Measurement.....  | 71        |



|            |   |     |
|------------|---|-----|
| <b>V</b>   | <b>SHEEP-OIL PALM INTEGRATION SYSTEM: YIELD,<br/>BOTANICAL COMPOSITION AND NUTRITIVE<br/>VALUE OF HERBAGE UNDER OIL PALM<br/>PLANTATION</b> ..... | 75  |
|            | Introduction.....   | 75  |
|            | Material and Methods.....   | 76  |
|            | Location of Study.....  | 76  |
|            | Botanical Composition of Herbage.....   | 76  |
|            | Herbage Yield Measurement.....  | 78  |
|            | Chemical Composition of Herbage.....  | 78  |
|            | Percentage of Light Penetration.....  | 78  |
|            | Statistical Analyses.....   | 79  |
|            | Results and Discussion.....   | 79  |
|            | Botanical Composition and Herbage Species.....  | 79  |
|            | Herbage Yield .....   | 83  |
|            | Nutritive Value of Herbage .....  | 87  |
|            | Conclusions.....  | 89  |
| <b>VI</b>  | <b>SHEEP-OIL PALM INTEGRATION SYSTEM:<br/>GRAZING BEHAVIOUR OF SHEEP</b> .....  | 91  |
|            | Introduction.....   | 91  |
|            | Material and Methods.....   | 93  |
|            | General Management.....   | 93  |
|            | Data Collection.....  | 93  |
|            | Statistical Analyses.....   | 96  |
|            | Results and Discussion.....   | 97  |
|            | Walking Distance and Energy Cost for Walking.....   | 97  |
|            | Grazing Preference.....   | 99  |
|            | Selective Herbage Yield (SHY).....  | 100 |
|            | Percentage of Selected Herbage DM digestibility<br>(% SHDMD).....   | 102 |
|            | Nutritive Value of Selected Herbage.....  | 104 |
|            | Conclusions.....  | 107 |
| <b>VII</b> | <b>SHEEP-OIL PALM INTEGRATION SYSTEM:<br/>GRAZING INTAKE AND STOCKING RATE<br/>OF SHEEP</b> .....   | 109 |
|            | Introduction.....   | 109 |
|            | Material and Methods.....   | 110 |
|            | Animal and Management.....  | 110 |
|            | Determination of Feed Intake.....   | 111 |



|             |  |            |
|-------------|--|------------|
|             | Estimation of Metabolisable Energy Intake .....  | 113        |
|             | Carrying Capacity.....   | 114        |
|             | Statistical Analyses.....  | 114        |
|             | Results and Discussion.....  | 115        |
|             | Pre-Weaning Lambs.....   | 115        |
|             | Grazing Sheep.....   | 118        |
|             | Carrying Capacity and Stocking Density.....  | 125        |
|             | Conclusions.....   | 129        |
| <b>VIII</b> | <b>SHEEP-OIL PALM INTEGRATION SYSTEM:<br/>GROWTH AND CARCASS PERFORMANCE<br/>OF SHEEP .....</b>    | <b>131</b> |
|             | Introduction.....  | 131        |
|             | Material and Methods.....  | 132        |
|             | Location and Size.....   | 132        |
|             | Animals and Management.....  | 133        |
|             | Data Collection.....   | 133        |
|             | Chemical Analyses .....  | 134        |
|             | Statistical Analyses.....  | 134        |
|             | Results and Discussion.....  | 135        |
|             | Live Weight Changes as the Age of<br>Sheep Increased.....  | 135        |
|             | Model that Described the Relationship<br>Between Weight and Age.....                               | 141        |
|             | Carcass Composition of Sheep.....  | 143        |
|             | Chemical Composition of the Carcass.....   | 159        |
|             | Relationship between Carcass Composition and Its<br>Chemical Composition on Empty Live Weight..... | 163        |
|             | Relationship Between Empty Live Weight<br>and Live Weight.....                                     | 165        |
|             | Conclusions.....   | 169        |
| <b>IX</b>   | <b>SHEEP-FEEDLOT SYSTEM: INTAKE AND<br/>GROWTH PERFORMANCE OF SHEEP .....</b>                      | <b>170</b> |
|             | Introduction.....  | 170        |
|             | Material and Methods.....  | 171        |
|             | Location.....  | 171        |
|             | Animal and Management.....   | 171        |
|             | Data Collection.....   | 173        |
|             | Calculation.....   | 173        |
|             | Chemical Analyses .....  | 174        |
|             | Statistical Analyses.....  | 174        |



|           |  |            |
|-----------|--|------------|
|           | Results and Discussion.....                              | 174        |
|           | Dry Matter Intake and Metabolisable                      |            |
|           | Energy Intake.....                                       | 174        |
|           | Live Weight Change.....                                  | 178        |
|           | Model that Describing the Relationship                   |            |
|           | Between Weight and Age.....                              | 179        |
|           | Carcass Composition of Sheep in                          |            |
|           | the Feedlot System.....                                  | 182        |
|           | Chemical Composition of the Sheep's Carcass.....         | 189        |
|           | Relationship between Empty Live Weight                   |            |
|           | and Carcass Composition.....                             | 191        |
|           | Relationship between Live Weight and                     |            |
|           | Empty Live Weight.....                                   | 195        |
|           | Conclusions.....   | 195        |
| <b>X</b>  | <b>COMPARISON OF PERFORMANCE AND MEAT</b>                |            |
|           | <b>PRODUCTION (AGE 6 TO 10 MONTHS) UNDER</b>             |            |
|           | <b>TWOPRODUCTION SYSTEMS.....</b>                        | <b>197</b> |
|           | Introduction.....  | 197        |
|           | Material and Methods.....                                | 198        |
|           | Number of Animal Used and Data Collection.....           | 198        |
|           | Statistical Analyses.....                                | 199        |
|           | Results and Discussion.....                              | 200        |
|           | Production Systems.....                                  | 200        |
|           | Breeds of Sheep.....                                     | 201        |
|           | Conclusions.....   | 207        |
| <b>XI</b> | <b>ENERGY UTILISATION OF SHEEP UNDER TWO</b>             |            |
|           | <b>PRODUCTION SYSTEMS.....</b>                           | <b>208</b> |
|           | Introduction.....  | 208        |
|           | Energy Utilisation for the Growing Sheep.....            | 209        |
|           | Estimates of Metabolisable Energy Intake.....            | 209        |
|           | Estimates of Metabolisable Energy Requirements.....      | 211        |
|           | Metabolisable Energy Requirement.....                    | 212        |
|           | Energy Utilisation for Carcass Composition Growth.....   | 217        |
|           | Estimates of Energy Retention in the Carcass Tissue..... | 217        |
|           | Estimate of Carcass, Muscle, Fat and                     |            |
|           | Bone Weight Gain.....                                    | 219        |
|           | Results and Discussion.....                              | 220        |
|           | Energy Utilisation in Sheep.....                         | 220        |
|           | Estimates of Energy Related to Gain.....                 | 239        |

|             |   |            |
|-------------|---|------------|
|             | Estimates of Weight Gain.....   | 243        |
|             | Conclusions.....  | 252        |
| <b>XII</b>  | <b>VALIDATION OF THE SIMULATION<br/>MODEL OF GROWTH AND MEAT<br/>PRODUCTION OF SHEEP UNDER<br/>DIFFERENT TWO PRODUCTION SYSTEM.....</b> | <b>253</b> |
|             | Introduction.....   | 253        |
|             | Material and Methods.....   | 254        |
|             | Performance of Sheep.....   | 254        |
|             | Validation of Growing Sheep on Model<br>Calculated Energy Intake.....   | 256        |
|             | Results and Discussion.....   | 261        |
|             | Integrated Oil Palm Plantation System.....  | 261        |
|             | Feedlot System.....   | 262        |
|             | Parameters used in the working of models.....   | 265        |
|             | Conclusions.....  | 270        |
| <b>XIII</b> | <b>GENERAL CONCLUSIONS AND DISCUSSION.....</b>  | <b>271</b> |
|             | <b>BIBLIOGRAPHY.....</b>  | <b>282</b> |
|             | <b>APPENDICES</b>   |            |
| A           | Additional Tables.....  | 301        |
| B           | Additional Figure.....  |            |
| C           | Additional Plates.....  | 315        |
| D           | Analysis of Growth Model Using SAS Programme.....   | 322        |
| E           | Carrying Capacity and Stocking Density.....   | 323        |
| F           | Estimation of the Energy Retained in Carcass<br>and its Tissues.....  | 324        |
| G           | Publications Related to the Study.....  | 332        |
|             | <b>VITA.....</b>  | <b>333</b> |



## LIST OF TABLES

| <b>Table</b> |   | <b>Page</b> |
|--------------|---|-------------|
| 1            | Examples of Simulation and Modelling in Animal Production Systems.....  | 16          |
| 2            | Equations for Five Growth Models and their Derived Traits.....  | 28          |
| 3            | Daily Nutrient Requirements of Sheep in the Tropics.....  | 41          |
| 4            | Chemical Composition of the Commercial Pellet Fed to Pre-weaning Lambs and Lactating Ewes.....  | 59          |
| 5            | Percentage of Major Herbage and Its Predominant Species at Different Ages of Oil Palm Plantation.....   | 80          |
| 6            | The Actual Herbage DM Yield (kg DM/ha/month) Compared with Predicted Model and Dahlan's Model and the % of Light Penetration under Oil Palm Canopy..... | 85          |
| 7            | The Chemical Composition of Herbage under Oil Palm Plantation.....  | 88          |
| 8            | Mean Values of Walking Distance, Times Spend, Speed and Walking Energy Expenditure of Sheep under Mature Oil Palm Plantation.....                       | 97          |
| 9            | Selective Index, Biological Index and Preference Index of Herbage Groups under Oil Palm Plantation.....   | 100         |
| 10           | Actual and Predicted Values of Selected Herbage Yield (SHY) and Selected Herbage DM digestibility (SHDMD).....  | 102         |
| 11           | Herbage Species taken by Grazing Sheep in the Mature Oil Palm Plantation.....   | 105         |



|    |  |     |
|----|--|-----|
| 13 | Means of Live Weight (LW), Chromium Concentration in Faeces (CRCF), Faecal Output (FO), FO/LW Value and Dry Matter Feed Intake (DMI) of the DSLT and DMalin Sheep under Oil Palm Canopy..... | 119 |
| 14 | Live Weight, Dry Matter Intake and Metabolisable Energy of DSLT and DMalin Sheep in Oil Palm Plantation at 5 Hours Daily.....  | 122 |
| 15 | Estimation of the DMI (g/kg LW <sup>0.75</sup> /d) and MEI (MJ/kg LW <sup>0.75</sup> /d) of Sheep at Different Levels of Grazing Periods.....  | 126 |
| 16 | Carrying capacity of DSLT and DMalin Sheep (AUE) at Different Ages of Oil Palm Plantations (Year).....   | 127 |
| 17 | Comparison of the Carrying Capacity of the Actual and Estimated Data from the Nutrient Requirements of Kearn (1982).....   | 128 |
| 18 | Growth Performance of DSLT and DMalin Sheep in the Mature Oil Palm Plantation System.....  | 137 |
| 19 | Means and Standard Error (SE) of Parameters of Non-Linear Function Fitted to the Growth Curves of DSLT and DMalin Sheep in Oil Palm Plantation.....  | 142 |
| 20 | Comparisons of Actual Live Weight and Predicted Live Weight (kg) at Different Ages of the DSLT and DMalin Sheep under Oil Palm Plantation .....  | 144 |
| 21 | Comparisons of the Mean of Body Composition at Different Breeds, Ages, and Sexes of Sheep in Oil Palm Plantation.....  | 145 |
| 22 | Means of Chemical Composition of Sheep's Carcass at Different Breeds and Sexes .....   | 160 |
| 23 | Allometric Equations of Carcass Chemical Composition to the Empty Live Weight Without Wool (ELWW) of Sheep under Integrated in Oil Palm Plantation.....                                      | 167 |



|    |  |     |
|----|--|-----|
| 24 | Comparison Weight of the Actual and Predicted Data of the Carcass Tissues, Carcass Protein and Carcass Fat (kg).....   | 168 |
| 25 | Chemical Composition of the Concentrate and Roughage which used for this Experiment.....   | 172 |
| 26 | Means of Live Weight Change, ADG, DMI, MEI, FCR of the DSLT and DMalin Sheep in the Feedlot System .....   | 177 |
| 27 | Means of Carcass Composition of the DSLT and DMalin Sheep in the Feedlot System .....  | 182 |
| 28 | Comparison of Actual Live Weight Means and Predicted Live Weight (kg) of Sheep in Feedlot System at the Age of 180 to 300 Days.....  | 183 |
| 29 | The Chemical Compositions of the DSLT and DMalin Sheep Carcass .....   | 190 |
| 30 | Allometric Equations of Carcass Composition (T) to the Empty Live Weight Without Wool (ELWW) of Sheep in the Feedlot System.....   | 192 |
| 31 | Comparison of Actual and Predicted Weight of Carcass Compositions of the Sheep in Feedlot System .....   | 194 |
| 32 | Least Square Mean (Lsmean $\pm$ SE) of Live Weight, ADG, DM and ME Intake of the DSLT and DMalin Sheep in Two Type of Production Systems.....  | 204 |
| 33 | Least Square Means (Lsmean $\pm$ SE) of Carcass Weight and Carcass Compositions of the DSLT and DMalin Sheep under Two Type of Production Systems.....   | 205 |
| 34 | Means of Metabolisable Energy Requirements, $NER_g$ (MJ/day, MJ/kg $LW^{0.75}$ /day) and $MER_g$ (kJ/g LW gain (kg $LW^{0.75}$ )) of the DSLT and DMalin Sheep at the Age of 2 and 4 Months Old..... | 223 |



|    |  |     |
|----|--|-----|
| 35 | Means of Metabolisable Energy Requirements, $NER_g$ (MJ/day, MJ/kg LW <sup>0.75</sup> /day) and $MER_g$ (kJ/g LW gain/kg LW <sup>0.75</sup> ) of the DSLT and DMalin Sheep at the Age of 6 to 14 Months Old..... | 225 |
| 36 | Means of Empty Live Weight and Retained Energy (MJ/kg ELWW <sup>0.75</sup> /day) in Carcass, Muscle of the DSLT and DMalin Pre-weaning Lambs.....  | 231 |
| 37 | Means of ELWW, $NER_g$ , Retained Energy in Carcass, Muscle, Fat and Bone (MJ/kg ELWW <sup>0.75</sup> /day) of the DSLT and DMalin Sheep at the Age of 6 to 14 Months Old.....                                   | 232 |
| 38 | Means of Metabolisable Energy Requirements, $NER_g$ (MJ/day, MJ kg LW <sup>0.75</sup> /day) and $MER_g$ (kJ/g LW gain/kg LW <sup>0.75</sup> ) of the DSLT and DMalin Sheep in the Feedlot System.....            | 235 |
| 39 | Means of ELWW, $NER_g$ , Retained Energy in Carcass, Muscle, Fat and Bone (MJ/kg ELWW <sup>0.75</sup> /day) of the DSLT and DMalin Sheep in the Feedlot System.....  | 240 |
| 40 | Comparisons between Actual and Predicted Data of $NER_g$ , LWG, DCG, DMG, DFG and DBG of Pre-Weaning Lambs.....  | 248 |
| 41 | Comparisons between Actual and Predicted Data of $NER_g$ , LWG, DCG, DMG, DFG and DBG of the Grazing Sheep under Oil Palm Canopy.....  | 249 |
| 42 | Comparisons between Actual and Predicted Data of $NER_g$ , LWG, DCG, DMG, DFG and DBG of the Fattened Sheep .....  | 251 |
| 43 | Live Weight of Sheep from Sungai Seraya Farm, Far East Holdings Bhd. Recorded between 1994 and 1995.....   | 255 |
| 44 | Parameter Values Used for the Simulation of Sheep Performance under Two Type of Production Systems.....  | 257 |





|    |   |     |
|----|---|-----|
| 45 | Actual and Simulated Data of Live Weight, Carcass and Its Tissue Weight (kg) of the Grazing DSLT and DMalin Sheep in the Mature Oil Palm Canopy.....                                | 263 |
| 46 | Actual (A) and Simulated (S) Data of Live Weight and Carcass and Its Tissue Weight (kg) of the DSLT and DMalin Sheep in Feedlot System.....   | 266 |
| 47 | Economic Analysis of Sheep reared in Oil Palm Plantation and Feedlot Systems (Based on Chapter X).....  | 301 |
| 48 | Chemical Composition of Selected Herbage under Oil Palm Plantation.....   | 302 |
| 49 | Means of Carcass Composition Weight (kg) and its Gain (grams/day) of Sheep Reared under Oil Palm Plantation.....  | 304 |
| 50 | Daily Weight Gain (grams/day) of Carcass, Muscle, Fat and Bone Weight of the DSLT and DMalin Sheep Reared under Oil Palm Plantation.....  | 305 |
| 51 | Comparison between Actual DMI and MEI with DMI and MEI estimated from the Nutrient Requirements of Kears (1982).....  | 306 |
| 52 | Means of Live Weight (LW), Dry Matter Intake (DMI), Metabolisable Energy Intake (MEI), Average Daily Gain (ADG) and Feed Conversion Ratio (FCR) of Sheep in the Feedlot System..... | 307 |
| 53 | Means of Carcass Composition Weight (kg) and its Gain (grams/day) of Sheep in Feedlot System.....   | 309 |
| 54 | Means of Live Weight and Retained Energy in Carcass, Muscle of the DSLT and DMalin Pre-weaning Lambs.....   | 310 |
| 55 | Means of LW, $NER_g$ , Retained Energy in Carcass, Muscle, Fat and Bone (MJ/day) of the DSLT and DMalin Sheep at the Age of 6 to 14 Months old.....                                 | 311 |



|    |  |     |
|----|--|-----|
| 56 | Means of LW, $NER_g$ , Retained Energy in Carcass, Muscle, Fat and Bone (MJ/day) of the DSLT and DMalin Sheep in the Feedlot System.....                 | 312 |
| 57 | Comparisons between Actual and Simulated Data of Live Weight Gain and Carcass and Its Tissue Weight Gain of the Grazing Sheep under Oil Palm Canopy..... | 313 |
| 58 | Comparisons between Actual and Simulated Data of Live Weight Gain and Carcass and Its Tissue Weight Gain of the Grazing Sheep under Feedlot System.....  | 314 |
| 59 | Comparison between Actual and Predicted Data of $NER_g$ , LWG, DCG, DMG, DFG and DBG of the Pre-Weaning Sheep.....                                       | 314 |
| 60 | Comparison between Actual and Predicted Data of $NER_g$ , LWG, DCG, DMG, DFG and DBG of the Grazing Sheep.....   | 314 |
| 61 | Comparison between Actual and Predicted Data of $NER_g$ , LWG, DCG, DMG, DFG and DBG of the Fattened Sheep.....  | 315 |



## LIST OF FIGURES

| <b>Figure</b> |   | <b>Page</b> |
|---------------|---|-------------|
| 1             | Diagram Illustrating of the Major Conceptual Model of the Study.....  | 47          |
| 2             | Conceptual Model of Sheep Production under Oil Palm Plantation System.....  | 49          |
| 3             | Conceptual Model of Sheep Production in Feedlot System.....   | 50          |
| 4             | Flow of Energy Metabolism in the Sheep.....   | 52          |
| 5             | Diagram of Energy used for Production or Energy Stored.....   | 56          |
| 6             | Planimeter (Core-Junior; G. Coradi AG Zurich, Switzerland) used to Measure the Rib Eye Area of Sheep.....   | 73          |
| 7             | Rib-Eye Area and the Location of the Fat Measurement Over the Rib-Eye Area.....   | 74          |
| 8             | Botanical Composition of Herbage under the Oil Palm Canopy at Different Ages of Oil Palm.....   | 82          |
| 9             | Percentage of DMD of Herbage in Oil Palm Plantation and Light Penetration under Oil Palm Canopy at Different Ages of Oil Palm.....                                  | 84          |
| 10            | Herbage Dry Matter Yield (kg DM/ha/month) under Various of Palm Ages.....   | 86          |
| 11            | Comparisons of (a) Selected Herbage DM Yield (SHY) and Its Prediction Model and (b) Selected Herbage Dry Matter Digestibility (SHDMD) and Its Prediction Model..... | 103         |
| 12            | Actual DM Intake (DMI, Kg/Day) and Predicted DMI of the Grazing Sheep under the Mature Oil Palm Canopy.....   | 124         |
| 13            | Relationship of Live Weight and Age of DSLT and DMalin Sheep in Oil Palm Plantation.....  | 139         |
| 14            | Actual Live Weight and Simulated Live Weight of DSLT and DMalin Sheep under Oil Palm Plantation System.....   | 144         |



|    |  |     |
|----|--|-----|
| 15 | Relationship Between Empty Live Weight without Wool and Chilled Carcass Weight (CCW), Carcass Weight without Fat (FFCW), Meat, Fat, and Bone Weight of a) DSLT Male, b) DSLT Female, c) DMalin Male and d) DMalin Female Sheep under Oil Palm Plantation System.....                               | 154 |
| 16 | Distribution of the Chemical Composition in the Carcass of a) DSLT Male, b) DSLT Female, c) DMalin Male and d) DMalin Female Sheep.....  | 162 |
| 17 | Actual Dry Matter Intake (DMI) and Metabolisable Energy Intake (MEI) of sheep compared to the DMI and MEI Calculated from the Nutrient Requirements of Kearl (1982).....   | 176 |
| 18 | Actual live weight of the DSLT and DMalin sheep in feedlot system.....   | 180 |
| 19 | Comparison between (a) Live Weight of Grazing and Fattened Sheep; (b) Live Weight of DSLT and DMalin Sheep, (c) Carcass and Its Tissues Weight of Grazing and Fattened Sheep and (d) Carcass and Its Tissues Weight of the DSLT and DMalin Sheep.....  | 206 |
| 20 | Fasting metabolism of the grazing sheep under oil palm canopy a) for male and b) for female sheep.....   | 222 |
| 21 | Comparison Between Actual □ and Simulated ■ Live Weight; Actual △ and Simulated ▲ Carcass Weight; Actual ▽ and Simulated ▼ Muscle Weight; Actual ☆ and Simulated ★ Fat Weight; and Actual ○ and Simulated ● Bone Weight of the DSLT and DMalin sheep reared in the Mature Oil Palm Plantation..... | 264 |
| 22 | Comparison Between Actual □ and Simulated ■ Live Weight; Actual △ and Simulated ▲ Carcass Weight; Actual ▽ and Simulated ▼ Muscle Weight; Actual ☆ and Simulated ★ Fat Weight; and Actual ○ and Simulated ● Bone Weight of the DSLT and DMalin sheep reared in the feedlot system.....             | 267 |
| 23 | Flow Diagram of Sheep in Oil Palm Plantation Production System.....  | 268 |
| 24 | Flow Diagram of Sheep in Feedlot System.....   | 269 |



## LIST OF PLATES

| <b>Plate</b> |   | <b>Page</b> |
|--------------|---|-------------|
| 1            | Precimeter used to Measure the Walking Distance of Grazing Sheep under Oil Palm Plantation .....      | 95          |
| 2            | Mature Oil Palm Plantation (Age of 13 year) and Green Vegetation under Oil Palm Canopy.....           | 316         |
| 3            | Sheep Grazing under Mature Oil Palm Canopy (16 Years Old).....  | 316         |
| 4            | Carcass of Grazing Sheep Under Mature Oil Palm Canopy Without Concentrate Supplementation.....        | 317         |
| 5            | Carcass Characteristic of Sheep in Feedlot System.....  | 318         |
| 6            | Carcass of Sheep Reared under Oil Palm Plantation Compared to Carcass of Sheep in Feedlot System..... | 319         |



## LIST OF ABBREVIATIONS

|                    |  |
|--------------------|--|
| ADG                | Average Daily Gain                           |
| AHP                | Area for Herbage Production per Hectare      |
| ANHP               | Area Not for Herbage Production              |
| AUE                | Animal Unit Equivalent                       |
| A                  | Asymptotic Weight                            |
| BC                 | Botanical Composition                        |
| BI                 | Biological Index                             |
| CAR <sub>FAT</sub> | Carcass Fat                                  |
| CAR <sub>PRO</sub> | Carcass Protein                              |
| CC                 | Carrying Capacity                            |
| CE                 | Carcass Energy                               |
| CF                 | Crude Fibre                                  |
| cm                 | Centimetre (s)                               |
| CP                 | Crude Protein                                |
| CRCF               | Chromium Concentration in One Gram of Faeces |
| CW                 | Carcass Weight                               |
| CCW                | Chilled Carcass Weight                       |
| DBG                | Daily Bone Gain                              |
| DCG                | Daily Carcass Gain                           |
| DE                 | Digestible Energy                            |
| DFG                | Daily Fat Gain                               |
| DM                 | Dry Matter                                   |
| DMalin             | Dorset x Malaysian Indigenous Breed          |
| DMD                | Dry Matter Digestibility                     |
| DMG                | Daily Muscle Gain                            |
| DMI                | Dry Matter Intake                            |
| DP                 | Dressing Percentage                          |
| DSL                | Dorset x Siamese Long Tail                   |
| e (or exp)         | Exponential                                  |
| EE                 | Ether Extract                                |
| E <sub>F</sub>     | Energy Concentration from Fat                |
| ELW                | Empty Live Weight                            |
| ELWW               | Empty Live Weight Without Wool               |
| E <sub>PROT</sub>  | Energy Concentration from Protein            |
| EV <sub>g</sub>    | Energy Value of Gain                         |
| FCR                | Feed Conversion Ratio                        |
| FD                 | Fat Depth                                    |
| FFCW               | Fat Free Carcass Weight                      |
| FI                 | Feed Intake                                  |
| FM                 | Fasting Metabolism                           |



|                   |   |
|-------------------|---|
| FO                | Faecal Output   |
| FPA               | Four Palm Area  |
| F-value           | Faecal Output / Live Weight                                       |
| g                 | Gram (s)  |
| GE                | Gross Energy  |
| GM                | Gradient Movement   |
| GR                | Relative Growth Coefficient                                       |
| ha                | Hectare (s)   |
| HDMY              | Herbage Dry Matter Yield per Hectare per Month                    |
| HI                | Herbage Intake  |
| HM                | Horizontal Movement   |
| J                 | Joule (s)   |
| $k_g$             | Efficiency of Utilisation of Metabolisable Energy for Gain        |
| kg                | Kilogram (s)  |
| kJ                | Kilojoule (s)   |
| $k_m$             | Efficiency of Utilisation of Metabolisable Energy for Maintenance |
| km                | Kilometre (s)   |
| ln                | Natural Logarithm   |
| Log <sub>10</sub> | Common Logarithm  |
| LP                | Light Penetration   |
| LS                | Level of Significance   |
| LW                | Live Weight   |
| M/B               | Meat/Bone Ratio   |
| M/F               | Meat/Fat Ratio  |
| ME                | Metabolisable Energy  |
| MEI               | Metabolisable Energy Intake                                       |
| MER               | Metabolisable Energy Requirement                                  |
| MER <sub>g</sub>  | Metabolisable Energy Requirement for Gain                         |
| MER <sub>GR</sub> | Metabolisable Energy Requirement for Growth                       |
| MER <sub>m</sub>  | Metabolisable Energy Requirement for Maintenance                  |
| min               | Minute (s)  |
| MJ                | Megajoule (s)   |
| ml                | Millilitre (s)  |
| MR                | Maturity Rate   |
| NA                | Nutrient Available  |
| NER <sub>g</sub>  | Net Energy Requirement for Gain                                   |
| NER <sub>m</sub>  | Net Energy Requirement for Maintenance                            |
| NFE               | Nitrogen Free Extract   |
| NPH               | Number of Palm per Hectare  |
| NS                | Non-significant difference ( $P>0.05$ )                           |
| NV                | Nutrient Value  |
| PA                | Palm Age  |
| PF                | Preference Index  |

|            |                                    |
|------------|------------------------------------|
| PHDMY      | Predicted Herbage Dry Matter Yield |
| PS         | Plot Size                          |
| q-value    | Metabolisability                   |
| $R^2$      | Coefficient of Determination       |
| RE         | Retained Energy                    |
| REA        | Rib Eye Area                       |
| $RE_B$     | Retained Energy in Bone            |
| $RE_{CAR}$ | Retained Energy in Carcass         |
| $RE_F$     | Retained Energy in Fat             |
| $RE_M$     | Retained Energy in Muscle          |
| RHGA       | Rate of Herbage Growth per Day     |
| SAS        | Statistical Analysis System        |
| SHDMY      | Selective Herbage Dry Matter Yield |
| SHY        | Selective Herbage Yield            |
| SI         | Selective Index                    |
| SLW        | Live Weight at Starved             |
| SLT        | Siamese Long Tail                  |
| TDN        | Total Digestible Nutrients         |
| TLW        | Transformed Live Weight            |
| VI         | Voluntary Intake                   |
| $W_t$      | Weight                             |



Abstract of the dissertation presented to the Senate of Universiti Putra Malaysia  
in fulfilment of the requirement for the Degree of Doctor of Philosophy

**SYSTEMS APPROACH TO EVALUATE GROWTH AND  
MEAT PRODUCTION OF SHEEP UNDER  
TWO PRODUCTION SYSTEMS**

By

**CHAIYAWAN WATTANACHANT**

**May 1999**

**Chairman: Professor Dahlan Ismail, Ph. D.**

**Faculty: Agriculture**

The growth and carcass performance of sheep reared under integration in the mature oil palm plantation and feedlot system were studied using a systems approach. Simulation models of the growth and carcass of the Dorset x Siamese Long Tail (DSLTL) and Dorset x Malin (DMalin) sheep were described.

To construct simulation models to evaluate a production system, a series of studies were carried out. Firstly, the dry matter intake, energy intake and energy requirements of sheep were determined. Secondly, the live weight changes, carcass, muscle, fat and bone weight changes were measured. Thirdly, the models were constructed to describe the growth and carcass performance of sheep under the two production systems. Validations of the simulation models were done by comparing the simulated data with the actual data of live weight, carcass and its tissue weight.

