Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
Aspects of Selection

for Economic Merit

in Dairy Cattle

A thesis
presented in partial fulfilment of the requirements
for the degree of

Doctor of Philosophy

in Animal Breeding at

Massey University

Gisela Ahlborn

1995
I gratefully acknowledge the guidance and support of my Chief Supervisor Professor Robert Anderson in my endeavours in mathematical and animal breeding statistics.

I would like to thank Professor Hugh Blair for the guidance of my work, his valuable comments on the manuscript and his friendly messages.

In particular, I would like to express my gratitude to Dr Brian Wickham of Livestock Improvement. His encouragement and support in many different ways made this study possible.

I would like to thank my supervisors Professor Al Rae and Dr Dorian Garrick for their help and advise.

I am grateful to my former colleagues at Livestock Improvement, Dr Pat Shannon, Rob Jackson and Dr John Rendel for sharing their ideas and knowledge with me.

I would like to thank Professor Bill Hohenboken, Professor Leo Dempfle and the late Dr Reuven Bar-Anan for their support and inspirations in matters animal breeding. I am indebted to Dr Bernhard Breier for his encouragement and practical advice and our stimulating academic discussions.

I am most grateful to Livestock Improvement to have provided me with this opportunity to further my education and contribute to dairy cattle breeding in New Zealand.

I am indebted to my parents who encouraged me to search for answers and taught me not to give up.

Finally, I would like to thank my husband Karl Matthys for his valuable comments on the manuscript of this thesis and his patience, encouragement and understanding during the final phase of my studies.
Economic merit of dairy cattle is an important consideration in dairy cattle breeding. In this thesis, genetic and economic aspects were combined to quantitatively derive an aggregate genotype with the aim to improve the economic merit of New Zealand dairy cattle.

Relative economic values for production traits, liveweight and survival rate were estimated. A profit function was defined for a pasture based milk production system. The effects of changes in several genetic, biological and economic parameters on various components of farm profit were simulated with a bioeconomic computer model.

The economic value for protein yield was $4.64/kg and $4.58/kg for Holstein-Friesian and Jersey cows, followed by $1.84/kg and $1.75/kg, respectively, for milkfat yield. Liveweight had a negative economic value of $0.49/kg and $0.53/kg for Holstein-Friesian and Jersey cows. An increase in survival rate by 1% had a positive economic value of $9.25 and $9.29 for Holstein-Friesian and Jersey cows. A sensitivity analysis showed that declining returns for milk reduced economic values for all milk components and simultaneously increased economic values for liveweight.

The effects of several traits on survival rate were quantified. An increase in survival rate increases a cow’s profitability as cows contribute to net farm income only during their lactation years and constitute a cost during the rearing period. After production traits, the farmer’s overall opinion of the cow and the traits udder support and udder overall had the greatest impact on survival rate. These traits were used as selection criteria for survival rate in the selection indexes.
Variance and covariance components were estimated with multitrait REML procedures for all production, management and conformation traits used in the current selection index. Heritabilities were 0.25 for protein yield and 0.21 for milkfat yield for Holstein-Friesians and 0.17 for both traits in Jerseys. Generally, parameter estimates did not differ substantially from other populations.

An aggregate genotype as well as selection indexes for Holstein-Friesians and Jerseys were constructed and weighting factors calculated based on the economic values and genetic parameters estimates.

The aggregate genotype included the traits protein yield, milkfat yield, volume, liveweight and survival rate.

The selection index for Holstein-Friesians included the traits protein yield, milkfat yield, volume, liveweight, udder overall, overall opinion, temperament, milking speed and udder support.

The selection index for Jerseys included the traits protein yield, milkfat yield, volume, liveweight, udder overall, overall opinion, temperament, milking speed and fore udder.

These selection indexes improve the economically important trait survival rate included in the aggregate genotype through indirect selection using traits which can be measured in the first lactation. This allows the current generation interval to be maintained when selection for survival rate is incorporated in the aggregate genotype.
TABLE OF CONTENTS

Abstract

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

2. SELECTION FOR MULTIPLE TRAITS - A REVIEW

2.1. Methods of selection for multiple traits

2.1.1. Tandem selection
2.1.2. Independent culling levels
2.1.3. Selection of extremes
2.1.4. Selection index methods

2.1.4.1. Optimum selection index
2.1.4.2. Best Linear Unbiased Prediction
2.1.4.3. Definition of aggregate genotype
2.1.4.4. Multiple-stage selection
2.1.4.5. Efficiency of selection index
2.1.4.6. Estimated selection index
2.1.4.7. Substitution index
2.1.4.8. Indices based on phenotypes
2.1.4.9. Selection indices with constraints
2.1.4.10. Alternatives to index selection

2.2. Estimation of relative economic values

2.2.1. Discount rates
2.2.2. Profit function - objective function
2.2.3. Methods of estimating rel. economic values
2.2.4. Use of economic indices
2.2.5. Non-linear economic values
2.3. Effects of errors in parameters on expected
genetic gain
  2.3.1. Errors in genetic parameters
  2.3.2. Errors in economic values

2.4. The current breeding objective for New Zealand
dairy cattle
  2.4.1. Selection objective
  2.4.2. Current selection criteria

3. A BIOECONOMIC MODEL

3.1. Introduction

3.2. A bioeconomic model for a pasture based milk
production system

3.3. Baseline parameters and variables
  3.3.1. Dairy farm production system parameters
  3.3.2. Metabolisable energy available
  3.3.3. Utilization/requirements of metabolisable
        energy
    a) Maintenance
    b) Lactation
    c) Prenatal growth
    d) Postnatal growth and weight gain

3.3.4. Biological animal variables
  a) Milk production
  b) Liveweight
  c) Replacement rate
  d) Age distribution of herd
    da) Estimation of age distribution
    db) Estimation of age-production factor
    dc) Effect on energy requirement for milk
    dd) Effect on revenue from cull cows
  e) Survival rate of cows
  f) Survival rate of calves (0 - 4 days)
  g) Survival rate of replacements (4 days
     - 2 years)
  h) Dressing percentage
  i) Ratio of calf weight at birth to cow
     liveweight
3.3.5. Economic variables
   a) Price for milkfat, protein and volume 89
   b) Price for carcass of mature cow 89
   c) Price for carcass of calf 90
   d) Price of calf sold for rearing 90
   e) Variable costs 91
   f) Fixed costs 92
   g) Discount rate 92

3.3.6. Objective variables 96

3.4. Validation of bioeconomic model 101
   3.4.1. Validation of conceptual model 101
   3.4.2. Verification of computerized model 102
   3.4.3. Operational validity 103

4. RELATIVE ECONOMIC VALUES ESTIMATED WITH THE BIOECONOMIC MODEL 107

4.1. Introduction 107

4.2. Material and methods 108

4.3. Milk production 111
   4.3.1. Protein 111
   4.3.2. Milkfat 118
   4.3.3. Lactose 126
   4.3.4. Volume 132

4.4. Liveweight 133
   4.4.1. Effects of liveweight changes 133
   4.4.2. Economic value of liveweight 135

4.5. Replacement rate 141

4.6. Comparison of economic values 145

5. SENSITIVITY ANALYSIS 146

5.1. Economic variables 150
   5.1.1. Returns for milk components 150
a) Heritabilities
b) Phenotypic correlations
c) Genetic correlations

7.4. Conclusion

8. SELECTION INDEXES

8.1. Introduction

8.2. Selection index equations

8.3. Results and discussion

8.4. Conclusion

9. CONCLUSION

10. APPENDIX

10.1. APL-code of bioeconomic model

10.2. APL-code for calculating selection index coefficients

10.3. Tables of genetic parameters for Holstein-Friesians, Jerseys and Ayrshires

10.4. Publications

11. PUBLICATIONS ARISING FROM THESIS

12. BIBLIOGRAPHY
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1. Flowchart of bioeconomic model.</td>
<td>63a</td>
</tr>
<tr>
<td>4.1. Revenue per ha from milk, sum of milk and bobby calves, sum of milk, bobby calves and cull cows and profit per ha defined as sum of revenue from milk, bobby calves and cull cows minus variable costs at different levels of protein yield per cow for Holstein-Friesians and Jerseys.</td>
<td>116</td>
</tr>
<tr>
<td>4.2. Revenue per ha from milk, sum of milk and bobby calves, sum of milk, bobby calves and cull cows and profit per ha defined as sum of revenue from milk, bobby calves and cull cows minus variable costs at different levels of milkfat yield per cow for Holstein-Friesians and Jerseys.</td>
<td>124</td>
</tr>
<tr>
<td>4.3. Revenue per ha from milk, sum of milk and bobby calves, sum of milk, bobby calves and cull cows and profit per ha defined as sum of revenue from milk, bobby calves and cull cows minus variable costs at different levels of lactose yield per cow for Holstein-Friesians and Jerseys.</td>
<td>131</td>
</tr>
<tr>
<td>4.4. Revenue per ha from milk, sum of milk and bobby calves, sum of milk, bobby calves and cull cows and profit per ha defined as the sum of revenue from milk, bobby calves and cull cows minus variable costs at different levels of liveweight for Holstein-Friesians and Jerseys.</td>
<td>140</td>
</tr>
<tr>
<td>4.5. Revenue per ha from milk, sum of milk and bobby calves, sum of milk, bobby calves and cull cows and profit per ha defined as the sum of revenue from milk, bobby calves and cull cows minus variable costs at different levels of replacement rate defined as the reciprocal of herdlife for Holstein-Friesians and Jerseys.</td>
<td>144</td>
</tr>
</tbody>
</table>
5.1. Real prices for milkfat and meat from cull cows and bobby calves during the last 20 years. 151

5.2. Changes in economic values for protein, milkfat, lactose and liveweight for Holstein-Friesians and Jerseys with an increasing price for protein. 155

5.3. Changes in economic values for protein, milkfat, lactose and liveweight for Holstein-Friesians and Jerseys with an increasing price for milkfat. 161

5.4. Changes in economic values for protein, milkfat, lactose and liveweight for Holstein-Friesians and Jerseys due to changes in volume penalty. 165
<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 3</td>
<td></td>
</tr>
<tr>
<td>3.1. Dairy farm production system parameters employed in the bioeconomic model.</td>
<td>64</td>
</tr>
<tr>
<td>3.2. Estimates for ME requirement for milk components.</td>
<td>74</td>
</tr>
<tr>
<td>3.2. Milk production statistics for 1990/91 season for Holstein-Friesians and Jerseys.</td>
<td>77</td>
</tr>
<tr>
<td>3.3. Statistical parameters for production per cow by age for Holstein-Friesians and Jerseys.</td>
<td>80</td>
</tr>
<tr>
<td>3.4. Proportion of cows in each age group for Holstein-Friesian and Jersey.</td>
<td>81</td>
</tr>
<tr>
<td>3.5. Age-production factors for Holstein-Friesian and Jersey for different replacement rates.</td>
<td>84</td>
</tr>
<tr>
<td>3.6. Expected dressing percentages for Holstein-Friesian and Jersey cows.</td>
<td>88</td>
</tr>
<tr>
<td>3.7. Variable costs per cow.</td>
<td>92</td>
</tr>
<tr>
<td>3.8. Total milking time estimates for Holstein-Friesian and Jersey cows.</td>
<td>97</td>
</tr>
<tr>
<td>3.9. Comparison of production parameters derived from an experiment and the bioeconomic model for Holstein-Friesians and Jerseys.</td>
<td>10</td>
</tr>
<tr>
<td>Chapter 4</td>
<td></td>
</tr>
<tr>
<td>4.1. Phenotypic and genetic parameters employed for Holstein Friesians and Jerseys.</td>
<td>11</td>
</tr>
</tbody>
</table>
4.2. Changes in energy requirements, revenue and cost per cow and per ha for Holstein-Friesians and Jerseys for different levels of protein yield. 113

4.3. Production parameters, profit per ha and economic values at different levels of protein yield per cow for Holstein-Friesian and Jersey cows. 117

4.4. Changes in energy requirements, revenue and costs per cow and per ha for Holstein-Friesians and Jerseys with different levels of milkfat yield. 120

4.5. Production parameters, profit per ha and economic values at different levels of milkfat yield per cow for Holstein-Friesians and Jerseys. 125

4.6. Changes in energy requirements, revenue and costs per cow and per ha for Holstein-Friesian with different levels of lactose yield. 128

4.7. Production parameters, profit per ha and economic values at different levels of lactose yield per cow for Holstein-Friesians and Jerseys. 132

4.8. Changes in energy requirements, revenue and costs per cow and per ha for Holstein-Friesians and Jerseys for different levels of liveweight. 137

4.9. Production parameters, profit per ha and economic values at different levels of liveweight for Holstein-Friesians and Jerseys. 141

4.10. Production parameters, profit per ha and economic values at different levels of replacement rate for Holstein-Friesians and Jerseys. 141

4.11. Comparison of decrease in stocking rates per phenotypic standard deviation increase in various traits for Holstein-Friesians and Jerseys. 141

4.12. Economic values per cow for Holstein-Friesians and Jerseys. 14
Chapter 5

5.1. Prices for milkfat, cull cow carcass and bobby calves.  

5.2. Changes in profit per ha and per cow with increasing protein prices for Holstein-Friesians and Jerseys.  

5.3. Changes in profit per ha and per cow and economic values for milk prices predicted for 2001 and 2011.  

5.4. Changes in profit per ha and per cow resulting from increasing milkfat prices for Holstein-Friesians and Jerseys.  

5.5. Changes in profit per ha and per cow due to an increased value for lactose for Holstein-Friesian and Jersey.  

5.6. Changes in profit per ha and per cow with increased costs for volume for Holstein-Friesian and Jersey.  

5.7. Changes in profit per ha and per cow resulting from changes in returns for cow meat for Holstein-Friesians and Jerseys.  

5.8. Changes in profit per ha and per cow resulting from changes in returns for calf meat for Holstein-Friesians and Jerseys.  

5.9. Changes in profit per cow and per ha with a 10% increase in variable costs, a 10% increase in stock prices and a 2% increase in interest rate for Holstein-Friesians and Jerseys.  

5.10. Changes in economic values per ha due to changes in DM grown, utilisation and energy content of DM.  

5.11. Changes in stocking rate, profit per ha and economic values per ha resulting from a 10% increase in biological variables for Holstein-Friesians and Jerseys.
Chapter 6

6.1. Number of cows with production, management and survival information at different lactations. 183

6.2. Means and standard deviations of production and non-production traits of primiparous cows included in the analysis. 185

6.3. Means and standard deviations for survival rates between subsequent lactations. 187

6.4. Partial regression coefficients for traits affecting survival rate from 1\textsuperscript{st} to 2\textsuperscript{nd} lactation. 188

6.5. Standardised partial regression coefficients for traits affecting survival rate from 1\textsuperscript{st} to 2\textsuperscript{nd} lactation. 190

6.6. Partial regression coefficients for traits affecting survival rate from 1\textsuperscript{st} to 3\textsuperscript{rd} lactation. 191

6.7. Partial regression coefficients for traits affecting survival rate from 1\textsuperscript{st} to 4\textsuperscript{th} lactation. 193

Chapter 7

7.1. Number of records for estimating variance and covariance components for production and non-production traits. 20

7.2. Heritabilities of selection objectives in the aggregate genotype and selection criteria in the selection indexes. 20

7.3. Phenotypic correlations between selection criteria included in the selection indexes. 21

7.4. Genetic correlations between traits in aggregate genotype and criteria in selection index. 22
Chapter 8

8.1. Phenotypic variances and covariances used for determining weighting factors for selection indexes. 224

8.2. Genetic variances and covariances used in determining weighting factors for selection indexes. 226

8.3. Weighting factors ($/cow/annum) for selection criteria included in the selection indexes $I_w$ (Holstein-Friesians) and $I_J$ (Jerseys). 228

Chapter 10 - Appendix

10.1. Adjusted means, phenotypic and additive genetic variances and heritability estimates with their standard deviations and standard errors for production and non-production traits for primiparous Holstein-Friesian, Jersey and Ayrshire cows. 242

10.2. Heritability and phenotypic and genetic correlation estimates for primiparous Holstein-Friesian, Jersey and Ayrshire cows. 245

10.3. Standard errors for heritability and phenotypic and genetic correlation estimates for primiparous Holstein-Friesian, Jersey and Ayrshire cows. 248