

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.

**DEVELOPING SELECTION INDEXES & ESTIMATION OF GENETIC  
PARAMETERS FOR TRAITS OF ECONOMIC IMPORTANCE IN DAIRY  
CATTLE UNDER ONCE-A-DAY MILKING**

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

**Doctor of Philosophy**

in

Animal Science

**Institute of Veterinary, Animal Biomedical Sciences  
Massey University  
Palmerston North, New Zealand**

**Felipe Lembeye Illanes**

**2016**







## **Abstract**

### **Developing Selection Indexes & Estimation of Genetic Parameters for Traits of Economic Importance in Dairy Cattle under Once-a-Day Milking.**

**PhD Thesis, Massey University, New Zealand**

In New Zealand, about 5% of dairy herds are milked once-a-day (OAD). The cows are inseminated using sires from the twice-a-day milking system (TAD) evaluated on breeding worth (BW) or an OAD selection index. Testing for sire-by-milking frequency (MF) interaction (S×MF) could reveal if developing an OAD-specific selection scheme is justified. In this thesis production records were analysed from herds milked OAD and an equivalent TAD population provided by Livestock Improvement Corporation. Across MF, heritabilities ( $h^2$ ) and genetic correlations were similar for milk yields ( $h^2$ : 0.21-0.36), although they tended to be greater in TAD. Genetic correlations were 0.35-0.40 between milk and fat yields, 0.85 between milk and protein yields and 0.54-0.60 between fat and protein yields. Observed rank correlation between OAD and TAD EBVs of the sires were moderate to high for milk yields, being greater in Jersey (J) (0.74-0.84) sires compared to Holstein-Friesian (F) and F×J crossbred (0.55-0.77) sires. Those values were greater than their critical values of the expected correlations (5th percentile), indicating that S×MF was not significant. Data from a university herd indicated that J cows were more efficient at production of milk solids (MS; fat + protein) per 100 kg of live weight than F or F×J cows milked OAD. In comparison, data from commercial herds milked either OAD or TAD indicated that F cows milked OAD had 19%-25% lower milk yields, whilst the reduction in yields from F×J and J cows was around 15%-19%. Breed effects (F-J) were lower on OAD compared to TAD systems, but heterosis effects were similar across MF (4.1%-7.6%). Under a progeny testing selection scheme for herds milked OAD, estimated genetic gains ranged from 3.3 to 3.7 kg/year for MS. Nevertheless, genetic gain resulting from the selection of bulls generated in TAD systems and dedicated to OAD herds would result in a similar increase compared with a separate scheme (only 11%-13% less of MS), indicating that there is little advantage in the implementation of a separate selection scheme. The main conclusion was that the S×MF interaction was not significant and farmers operating under OAD milking achieve similar genetic gain using sires from the TAD milking selection scheme but ranked on an OAD-selection index.



*This thesis is dedicated to my dear wife Macarena, my son Pedro Felipe, and to the memory of my late father, Jorge.*





## **Declaration**

This thesis contains no material that has been accepted for a degree or diploma by the University or any other institution. To the best of knowledge no material previously published or written by another person has been used, except where due acknowledgement has been made in text.

This thesis has been written with chapters formatted as papers for publication. Therefore there is some repetition of introduction and methods sections. Each chapter contains a full discussion, with the final general discussion chapter providing a succinct discussion of key findings of this thesis.



## Acknowledgements

Firstly, I wish like to express my sincere gratitude to my supervisor Professor Nicolás López-Villalobos for accepting me as one his students, for his assistant, guidance, constant challenge in my research and more importantly, patience. His teaching in simulation, genetic and mathematics statistics has strongly contributed to my growth as a scientist.

I acknowledge my co-supervisors Dr. Jennifer Burke and Dr. Steve Davis. Both were always willing to attend my meetings, to improve my scientific writing and provide accurate advice in the structure of the chapters.

Special thanks to my friend Dr. Nicholas Sneddon for his friendly support and useful conversation during my doctoral studies. Also, special thanks to Igor Solar for his assistance and help in my writing.

I am grateful to my mother, Gladys Illanes and godparents, Manuel Sánchez and María Arjona. They always believed in my abilities and supported me when I needed them most during my time in New Zealand.

I acknowledge Conicyt Becas Chile for their financial support that allowed me to study for a PhD in New Zealand, and to LIC for providing the data for this research.

To all of IVABs staff, in particular to Miss Debbie Hill, Dr. Penny Back, Dr. Sam Peterson, Prof. Kevin Stafford, and Dr. Sarah Pain and to Massey University Dairy 1 farm manager Jolanda Amoore.

Thanks to my all friends, especially to Juan and Daniela, Javier and Sarah, Rex, José and Elizabeth, Martín and Manuela, and my office mates Kandarp, Emilie, Alfredo, Nick, Alan and Ali for providing a friendly environment and great (funny) talks.

Lastly, but not less important, many thanks to my wife Macarena for always being at my side and putting up with me throughout this study. This achievement belongs to her as well.

## Contents

Abstract .....	i
Declaration .....	v
Acknowledgements .....	vii
Contents .....	viii
List of Tables .....	ix
List of Figures .....	xiv
List of Appendices .....	xvi
List of Abbreviations .....	xvii
CHAPTER 1	
General introduction.....	1
CHAPTER 2	
Literature review .....	7
CHAPTER 3	
Comparative performance in Holstein-Friesian, Jersey, and crossbred cows milked once daily under a pasture-based system in New Zealand.....	41
CHAPTER 4	
Milk production of Holstein-Friesian, Jersey and crossbred cows milked once-a-day or twice-a-day in New Zealand .....	61
CHAPTER 5	
Breed and heterosis effects for milk yield traits at different production levels, lactation number and milking frequencies .....	85
CHAPTER 6	
Estimation of genetic parameters for milk traits in cows milked once- or twice-daily in New Zealand .....	101
CHAPTER 7	
Comparison of sire breeding values for milk yields traits based on daughters milked once- or twice-daily in New Zealand .....	123
CHAPTER 8	
Selection scheme designs for dairy cattle milked once daily in New Zealand: a deterministic approach .....	143
CHAPTER 9	
General discussion.....	175
Statement of contributions .....	193

## List of Tables

<b>Table 2.1.</b> Mean values for annual yields of milk yield traits over a full lactation from dairy cows milked once-a-day (OAD) or twice-a-day (TAD) in Holsteins Friesian (F), Jersey (J) and crossbred cows (F×J).....	11
<b>Table 2.2.</b> Correlation coefficients between once- and twice-a-day breeding values for milk yield and somatic cell score. ....	22
<b>Table 2.3.</b> Population size, population selected number of records and generation intervals in the New Zealand dairy cattle.....	29
<b>Table 3.1.</b> Mean, standard deviation (SD), minimum and maximum values for the total lactation record of milk, fat and protein yield, and average somatic cell score, live weight and body condition score of all dairy cows at Massey University dairy farm No. 1 during the dairy seasons 2013-2014 and 2014-2015. ....	49
<b>Table 3.2.</b> Estimated Pearson linear correlation and standard error for actual and predicted daily milk, fat and protein yield, somatic cell score, live weight and body condition score modelled with a third-order orthogonal polynomial fitted to Holstein-Friesian (F), Jersey (J) and F×J crossbred cows under once-a-day milking at Massey University dairy farm No. 1. ....	50
<b>Table 3.3.</b> Least squares means and standard errors of the estimates of regression coefficients of the lactation curves for milk (MY), fat (FY) and protein (PY) yields, somatic cell score (SCS), live weight (LW) and body condition score (BCS) modelled with a third-order orthogonal polynomial fitted to Holstein-Friesian (F), Jersey (J) and F×J crossbred cows under once-a-day milking at Massey University dairy farm No. 1. ....	51
<b>Table 3.4.</b> Predicted means and standard errors of lactation length, total lactation yields of milk, fat and protein, average somatic cell score, live weight and body condition score, peak and persistency of milk yield of Holstein-Friesian, Jersey and crossbred cows under once-a-day milking at Massey University dairy farm No. 1. ....	52
<b>Table 3.5.</b> Least squares means and standard errors of predicted total dry matter intake, feed conversion efficiency, biological efficiency, dry matter intake capacity of Holstein-Friesian, Jersey and crossbred cows under once-a-day milking at Massey University dairy farm No. 1. ....	54

<b>Table 4.1.</b> Number of herd-test records, number of lactations and cows per milking frequency and breed group.....	66
<b>Table 4.2.</b> Least square means and standard errors of regression coefficients of the lactation curve for milk yield modelled with a fifth-order Legendre polynomial fitted to Holstein-Friesian (F), Jersey (J) and first F×J crossbred cows of different lactation number and milking frequency (MF).....	71
<b>Table 4.3.</b> Least square means and standard errors (x102) of regression coefficients of the lactation curve for fat yield modelled with a fifth-order Legendre polynomial fitted to Holstein-Friesian (F), Jersey (J) and first F×J crossbred cows of different lactation number and milking frequency (MF).....	72
<b>Table 4.4.</b> Least square means and standard error (x102) of regression coefficients of the lactation curve for protein yield modelled with a fifth-order Legendre polynomial fitted to Holstein-Friesian (F), Jersey (J) and first F×J crossbred cows of different lactation number and milking frequency (MF). ....	73
<b>Table 4.5.</b> Least squares means and standard error of regression coefficients of the somatic cell curve modelled with a fifth-order Legendre polynomial fitted to Holstein-Friesian (F), Jersey (J) and F×J crossbred cows of different lactation number and milking frequency (MF).....	74
<b>Table 4.6.</b> Predicted least square means with standard errors of total yields of milk, fat and protein, and average somatic cell score (SCS) in New Zealand dairy cattle, by milking frequency (MF), breed group and lactation number.....	76
<b>Table 4.7.</b> Predicted least square means with standard errors of lactation persistency of milk, fat and protein yield in New Zealand dairy cattle, by milking frequency (MF), breed group and lactation number. ....	77
<b>Table 5.1.</b> Number of herds and lactations, and mean of milk solids (kg/cow) by production level and milking frequency.....	91
<b>Table 5.2.</b> Predicted means and standard errors of production traits for Holstein-Friesian (F), Jersey (J) and first cross (F <sub>1</sub> ) F×J cows and estimates of breed and heterosis effects by milking frequency and lactation number.....	92
<b>Table 5.3.</b> Predicted means and standard errors of production traits for Holstein-Friesian (F), Jersey (J) and first cross (F <sub>1</sub> ) F×J cows and estimates of breed and heterosis effects at different production levels. ....	93
<b>Table 6.1.</b> Mean (coefficient of variation, %) for milk production traits by breed group and milking frequency (MF).....	106

<b>Table 6.2.</b> Estimates of variance components, heritabilities and repeatabilities with their respective standard errors of the mean for milk production traits in the once-a-day milking population. ....	111
<b>Table 6.3.</b> Estimates of variance components, heritabilities and repeatabilities with their respective standard errors of the mean for milk production traits in the twice-a-day milking population. ....	111
<b>Table 6.4.</b> Estimates of genetic (below the diagonal) and phenotypic (above the diagonal) correlations, with their standard errors of the mean, for the milk production traits in the once-a-day milking population. ....	114
<b>Table 6.5.</b> Estimates of genetic (below the diagonal) and phenotypic (above the diagonal) correlations, with their standard errors of the mean for the milk production traits in the twice-a-day milking population. ....	114
<b>Table 7.1.</b> Genetic parameters of total lactation yields of milk, fat, protein and average somatic cell score used to calculate expected correlations. ....	132
<b>Table 7.2.</b> Mean and standard deviation (SD) of total days in milk, total lactation yields of milk, fat, protein (kg/cow) and average somatic cell score by lactation number of the progeny of 242 sires with at least 20 daughter progeny per milking frequency system. ....	133
<b>Table 7.3.</b> Estimated breeding values and reliabilities for production traits of sires evaluated with progeny in either once- or twice-daily milking systems. ....	134
<b>Table 7.4.</b> Estimates of regression coefficients (intercept and slope) of estimated breeding values (EBVs) for milk traits from once-a-day (OAD) milking herds on EBV for the same traits from twice-a-day (TAD) milking herds for 86 Holstein-Friesian sires. Spearman's rank ( $r_s$ ) correlations between OAD and TAD EBVs and the corresponding mean and critical values of the expected correlations ( $r_E$ ) at different true genetic correlations ( $r_G$ ) of the same trait expressed in two environments are also shown. ....	135
<b>Table 7.5.</b> Estimates of regression coefficients (intercept and slope) of estimated breeding values (EBVs) for milk traits from once-a-day (OAD) milking herds on EBV for the same traits from twice-a-day (TAD) milking herds for 60 crossbred Holstein-Friesian $\times$ Jersey sires. Spearman's rank ( $r_s$ ) correlations between OAD and TAD EBVs and the corresponding mean and critical values of the expected correlations ( $r_E$ ) at different true genetic correlations ( $r_G$ ) of the same trait expressed in two environments are also shown. ....	135



<b>Table 7.6.</b> Estimates of regression coefficients (intercept and slope) of estimated breeding values (EBVs) for milk traits from once-a-day (OAD) milking herds on EBV for the same traits from twice-a-day (TAD) milking herds for 96 Jersey sires. Spearman's rank ( $r_s$ ) correlations between OAD and TAD EBVs and the corresponding mean and critical values of the expected correlations ( $r_E$ ) at different true genetic correlations ( $r_G$ ) of the same trait expressed in two environments are also shown.....	136
<b>Table 7.7.</b> Estimates of regression coefficients (intercept and slope) of estimated breeding values (EBVs) for milk traits from once-a-day (OAD) milking herds on EBV for the same traits from twice-a-day (TAD) milking herds for 242 sires. Spearman's rank ( $r_s$ ) correlations between OAD and TAD EBVs and the corresponding mean and critical values of the expected correlations ( $r_E$ ) at different true genetic correlations ( $r_G$ ) of the same trait expressed in two environments are also shown.....	136
<b>Table 8.1.</b> Population size, population selected, proportion selected and selection intensities for a progeny testing selection scheme for the dairy cattle population milked twice-a-day.....	149
<b>Table 8.2.</b> Population size, population selected, proportion selected and selection intensities for a progeny testing selection scheme in the population milked once-a-day.....	150
<b>Table 8.3.</b> Population size, population selected, proportion selected and selection intensities for a genomic selection scheme in the population milked once-a-day.....	152
<b>Table 8.4.</b> Economic values (EV) and relative emphasis (RE) for traits in breeding worth, the theoretical once-a-day selection index, and different selection objectives investigated for the dairy cattle milked once-a-day.....	155
<b>Table 8.5.</b> Genetic (below the diagonal) and phenotypic (above the diagonal) parameters among traits in the breeding worth and udder traits of dairy herd populations milked once- or twice-a-day.....	157
<b>Table 8.6.</b> Approximation of genetic correlations among milk yields and somatic cell score (SCS) under once- and twice-a-day milking systems.....	158
<b>Table 8.7.</b> Correlated response per year in the New Zealand dairy population milked once-a-day (OAD) resulting from selecting bulls progeny tested under twice-a-day (TAD) systems, and for a separate progeny testing OAD selection scheme based on alternative selection objectives. ....	160

**Table 8.8.** Asymptotic annual response ( $\Delta G$ ) of the aggregate breeding value (\$ expressed in genetic standard deviation [ $\sigma_g$ ] per year) in the New Zealand dairy population milked once-a-day based on the traditional progeny testing and an approach to genomic selection..... 163

## List of Figures

<b>Figure 2.1.</b> Milk solid yields per cow in Holstein-Friesian and Jersey cows milked once-a-day (OAD) and twice-a-day (TAD). Bars represent standard deviation expressed as a percentage of the mean.....	19
<b>Figure 2.2.</b> Illustration of selection scheme based on genomic selection (Thomasen et al. 2014).....	31
<b>Figure 3.1.</b> Actual herd test record and predicted lactation curves of milk yield (kg/day) of <i>a</i> , Holstein-Friesian; <i>b</i> , F×J crossbred; and <i>c</i> , Jersey cows milked once-a-day at Massey University dairy farm No. 1. ....	53
<b>Figure 3.2.</b> Actual herd test record and predicted lactation curves of milk solids yield (kg/day) of <i>a</i> , Holstein-Friesian; <i>b</i> , F×J crossbred; and <i>c</i> , Jersey cows milked once-a-day at Massey University dairy farm No. 1. ....	46
<b>Figure 4.1.</b> Predicted milk yield from calving to 270 d of lactation across lactation (L1-L5) in cows milked once-a-day (a) and twice-a-day (b).....	75
<b>Figure 4.2.</b> Predicted milk yield from calving to 270 d of lactation of Holstein-Friesian, Jersey and F×J crossbred cows milked once-a-day ( <i>a</i> ) and twice-a-day ( <i>b</i> )....	75
<b>Figure 8.1.</b> Structure of the national progeny testing selection scheme and the selection system for once-a-day herds. Bull replacements originate from mating elite bulls (BB) and elite cows (CB). Cow replacement resulted from cows selected to breed cows (CC) mated with bulls selected to breed cows (BC).....	150
<b>Figure 8.2.</b> Structure of the proposed once-a-day progeny testing selection scheme. Bull replacements originate from mating elite bulls (BB) and elite cows (CB). Cow replacement resulted from cows selected to breed cows (CC) mated with bulls selected to breed cows (BC).....	151
<b>Figure 8.3</b> Structure of the proposed once-a-day genomic selection scheme. Bull replacements originate from mating elite bulls (BB) and elite cows (CB). Cow replacement resulted from cows selected to breed cows (CC) mated with bulls selected to breed cows (BC).....	152
<b>Figure 8.4.</b> Estimated genetic trends in milk yield (a), fat yield (b), protein yield (c) and live weight (d) in the once-a-day population resulting from the OAD <sub>SO1</sub> progeny testing selection scheme (solid line) and bulls selected by TAD <sub>SO1</sub> (dotted line) over a 25 year-period. TAD <sub>SO1</sub> = bulls selected under TAD systems which selection objective includes selection objective that includes lactation yields of	

milk, fat and protein, live weight, somatic cell score, fertility and residual survival.  
 OAD<sub>SO1</sub>= once-a-day selection objective 1 that includes same traits as those in  
 TAD<sub>SO1</sub>..... 161

**Figure 8.5.** Estimated genetic trends in milk yield (a), fat yield (b), protein yield (c)  
 and live weight (d) in the once-a-day population resulting from the OAD<sub>SO2</sub>  
 progeny testing selection scheme (solid line) and bulls selected by the TAD<sub>SO2</sub>  
 (dotted line) over a 25 year-period. TAD<sub>SO2</sub> = bulls selected under TAD systems  
 which selection objective includes lactation yields of milk, fat and protein, live  
 weight, somatic cell score, fertility, residual survival, udder support and milking  
 speed. OAD<sub>SO2</sub> = once-a-day selection objective 2 with the same traits as those in  
 TAD<sub>SO2</sub>..... 162

**Figure 8.6.** Estimated genetic trends for the aggregate breeding value (\$ expressed  
 in  $\sigma_g$ ) in the once-a-day population under OAD<sub>SO2</sub> (once-a-day selection objective 2  
 that includes lactation yields of milk, fat and protein, live weight, somatic cell  
 score, fertility, residual survival, udder support and milking speed) resulting from  
 traditional progeny testing (PT) and genomic selection. GS-40 = genomic selection,  
 40% reliability GS-50 = genomic selection, 50% reliability GS-60 = genomic  
 selection, 60% reliability..... 164

## List of Appendices

<b>Appendix 7.1.</b> Derivation of (co)variance matrix <b>V</b> .....	142
<b>Appendix 8.1.</b> Derivation of co(variance) matrices in bull and cows pathways of selection. ....	172
<b>Appendix 8.2.</b> Construction of matrix <b>G</b> in bull pathways when they are tested in twice-a-day and used in once-a-day systems .....	173

## List of Abbreviations

MF = Milking frequency

OAD = Once-a-day

TAD = Twice-a-day

F = Holstein-Friesian

J = Jersey

F×J = Holstein-Friesian × Jersey crossbred

MY = Milk yield

FY = Fat yield

PY = Protein yield

SCS = Somatic cell score

MS = Milk solids

PL = Production level

BW = Breeding Worth

EBVs = Estimated breeding values

G×E = Genotype by environment interaction

S×MF = Sire by milking frequency interaction

