

Optimised Livestock Breeding Programs Using Female Reproductive Technologies and Genomic Selection

Tom Granleese

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Abstract

This thesis explores various methods to optimise breeding programs that use female reproductive technologies and genomic selection. Simulation studies have shown that female reproductive technologies such as multiple ovulation and embryo transfer (MOET) and juvenile *in vitro* embryo production and transfer (JIVET) can increase rates of genetic gain through increased female selection intensity and decreased generation interval. Furthermore the use of genomic selection has facilitated better selection decisions to be made on younger selection candidates that may not have phenotypic measurements. When combining genomic selection with reproductive technologies the rate of genetic gain could be further accelerated. However intensive use of the best females in breeding programs can also increase the rate of inbreeding to unsustainable levels. This thesis aimed to stochastically simulate breeding programs where reproductive and genomic technologies are optimally implemented while maintaining a sustainable increase of inbreeding. The impacts of using reproductive technologies and/or genomic selection were evaluated for breeding programs across species. Furthermore, the thesis investigated a cost-benefit analysis of using reproductive technologies which led to a further study that optimized the use of reproductive technologies that considered their costs as well as future co-ancestry during selection.

The first experiment investigated the genetic implications of using a combination of artificial insemination or natural mating (AI/N), MOET and JIVET as well as genomic selection. A stochastic simulation that used optimal contribution selection to optimise allocation of female reproductive technologies while using a range of penalties on co-ancestry was used. This study was conducted for sheep and cattle where a single trait was measured early or later in life, or sex-limited as in dairy breeding programs. Results showed that all breeding programs could reach high rates of inbreeding if the co-ancestry was not penalised when selecting future parents. It was also observed that if co-ancestry was penalised too heavily, very low rates of genetic gain were achieved. A balance could be found with levels of genetic gain close to the maximum while inbreeding was kept at a sustainable rate. We observed the addition of MOET to be beneficial to all breeding programs. The further addition of JIVET was not beneficial when genomic selection was not used apart from small gains observed in early measured traits of sheep and beef. When genomic selection was used, all breeding programs were observed to increase rates of genetic

gain and the use of MOET as well as JIVET was always beneficial for achieving more gain; with AI/N+MOET+JIVET breeding programs yielding the highest genetic gain. Late measured traits in beef and sheep and the sex-limited dairy trait benefited relatively more from genomic selection and there was evidence to suggest that strong synergies existed between use of reproductive technologies and genomic selection.

The second study investigated the impact of using two sheep multiple trait indexes that are currently used in the Australian sheep industry with the aim to evaluate the benefit for some real indexes and to compare the emphasis placed on the improvement of the various traits within the index. The same methodology was used as the first experiment. We used a terminal index where all traits are measured in the first 5 months of life. The second index was the dual purpose Merino index where most traits are measured around 2 years of age. In the terminal index breeding programs, genetic gain accelerated by up to 71% when reproductive technologies were used. The Merino index also increased by up to 85%. We observed genomic selection to provide larger benefits to traits that were measured later in life or not at all. The Merino breeding programs had much larger index gains in dollar terms but the terminal breeding program yielded higher rates of genetic gain when measured in genetic standard deviations of the index.

The third experiment carried out a cost-benefit analysis (CBA) of a sheep producer who bred rams in a closed system with a nucleus (tier 1) producing rams for a 10,000 head commercial flock (tier 2). A deterministic model was used with the tier 1 parameters derived from the second experiment. The dissemination of genetics from tier 1 to tier 2 was modelled based on the gene-flow methodology to accurately account the impact of genetic improvement over time. CBA was calculated for both terminal and Merino indexes. Both programs observed that using reproductive technologies is a large investment up-front and debt is accumulated. All breeding programs were profitable over 20 years in both indexes. However using genomic selection was less profitable in the terminal index apart from when JIVET was used. The use of reproductive technologies reduced economic gains over 20 years in all other terminal breeding programs. The Merino index resulted in larger economic benefits overall but the use of reproductive technologies could only be justified when combined genomic selection. It was

concluded that cost of reproductive technologies should be included when allocating selected females to reproductive technologies in nucleus breeding programs.

The final experiment used again a stochastic simulation of a breeding program with optimal selection using the same terminal and Merino indexes as in experiment 2. However, this time we accounted for the true cost of reproductive technology in the objective function of the optimal contribution selection. The benefit of increased genetic merit in the commercial tier was reflected by a premium on each selection candidate's EBV. This premium reflected various proportions of total benefit that was actually captured by the breeder. No reproductive technologies were assigned in the terminal breeding program and less than 4% in the MP+ index when the proportion captured by the breeder was 0.06. We observed as premiums increased, higher proportions of reproductive technologies were assigned and hence higher rates of genetic gain in both indexes. As MOET had a higher cost per lamb than JIVET, we observed a significantly lower number of MOET progeny compared to Chapter 4 where cost was not considered in selection decisions. By factoring in cost to breeding programs, it resulted in more practical and realistic breeding programs.

Declaration

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I also certify that any help received in preparing this thesis and all sources used have been acknowledged in this thesis.

A black rectangular box used to redact the signature of the author.

Tom Granleese

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Table of Contents

Abstract	2
Declaration	5
Acknowledgements	6
Table of Contents	7
List of Figures	11
List of Tables	12
Chapter 1. Introduction	15
Chapter 2. Review of Literature	20
2.1. Introduction	20
2.2. Reproductive Technologies	21
2.2.1. Multiple Ovulation and Embryo Transfer	21
2.2.2. Mature <i>In Vitro</i> Embryo Production and Embryo Transfer	22
2.2.3. Juvenile <i>In Vitro</i> Embryo Production and Embryo Transfer	22
2.3. Breeding Programs	23
2.4. Genomic Selection	25
2.5. Breeding Programs using Genomic Selection and Reproductive Technologies	26
2.6. Inbreeding	27
2.7. Modelling of breeding programs	29
2.8. Economics of using technologies in breeding programs	30
2.8. Conclusion	33
Chapter 3. Increased genetic gains in sheep, beef and dairy breeding programs from using female reproductive technologies combined with optimal contribution selection and genomic breeding values.	34
3.1. Abstract	35
3.2. Introduction	36
3.3. Methods	38
3.3.1. Simulation	38
3.3.2. Males Eligibility and Selection	39
3.3.3. Genomic Selection	40
3.3.4. Estimation of Breeding Values	40
3.3.4. Optimal Contribution Selection	41
3.3.5. Breeding Programs	42
3.3.6. Comparison of Breeding Programs	44
3.4. Results	45

3.4.1. Differences Between Breeding Programs When Not Using Genomic Selection	45
3.4.2. Differences Between Breeding Programs With Genomic Selection	50
3.4.3. Impact of Genomic Selection on Breeding Programs	50
3.5. Discussion	51
3.5.1. Breeding programs	51
3.5.2. Optimal contribution selection	52
3.5.3. Comparing with previous studies	53
3.5.4. Rates of inbreeding	55
3.5.5. Simulation restrictions	57
3.6. Conclusion	58
3.7. Competing interests	58
3.8. Authors' contributions	59
3.9. Acknowledgements	59
Chapter 4. Increased genetic gains in multiple sheep traits using female reproductive technologies combined with optimal contributions selection and genomic breeding values	62
4.1. Abstract	63
4.2. Introduction	64
4.3. Methods	66
4.3.1. Simulation	66
4.3.2. Males Eligibility and Selection	67
4.3.3. Females Eligibility and Selection	67
4.3.4. Genomic Selection	70
4.3.5. Estimating Breeding Values and Multi-Trait Indexes	70
4.3.6. Optimal Contribution Selection	71
4.4. Results	72
4.4.1. Inbreeding Rates	72
4.4.2. The Impact of Reproductive Technologies on the Breeding Program	72
4.4.3. The Impact of Reproductive Technologies on Breeding Programs Using Genomic Selection	74
4.4.3. Impact of genomic selection on each breeding program	77
4.5. Discussion	78
4.6. Conclusion	82
4.7. Competing interests	82
4.8. Authors' contributions	82
4.9. Acknowledgements	82

Chapter 5. Cost-benefit analysis of MOET and JIVET in 2-Tier sheep breeding program	85
5.1. Abstract	86
5.2. Introduction	86
5.3.1. Breeding programs parameters	88
5.3.2. Tier 1 Costs.....	91
5.3.3. Tier 1 Income	91
5.3.4. Tier 2 Income	92
5.3.5. Net Present Value	93
5.4. Results	95
5.4.1. Economic Impact of Reproductive Technologies without Genomic Selection	95
5.4.2. Economic Impact of Reproductive Technologies using Genomic Selection	96
5.4.3. Economic Impact of Genomic Selection on breeding programs	97
5.4.4. Economic Impact of Restricting Inbreeding.....	97
5.5. Discussion	99
5.6. Conclusion.....	106
5.7. Competing interests	106
5.8. Authors' contributions	106
5.9. Acknowledgements	106
Chapter 6. Optimised nucleus sheep breeding programs where cost of reproductive technologies are considered during selection.	109
6.1. Abstract	110
6.2. Introduction	111
6.3. Methods	112
6.3.1. Simulation.....	112
6.3.1. Males Eligibility and Selection.....	114
6.3.2. Breeding Programs	114
6.3.3. Genomic Selection.....	116
6.3.4. Estimating Breeding Values	117
6.3.5. Optimal Contribution Selection.....	117
6.3.6. Comparison of scenarios	119
6.4. Results	119
6.4.1. Impact of proportion of benefit paid EBV point	119
6.4.2. Impact of genomic selection.....	120
6.5. Discussion	121

6.6. Conclusion.....	128
6.7. Competing interests	128
6.8. Authors' contributions	128
6.9. Acknowledgements	128
Chapter 7. General Discussion	131
7.1. Benefits of female reproductive technologies and genomic selection across species	133
7.2. Breeding programs using multiple trait indexes.....	135
7.3. Cost benefit in two tiers.....	137
7.4. True costs factored into selection	139
7.5. Future research and extension	141
7.6. Recommendations	142
7.7. Conclusion.....	143
8. Consolidated Reference List.....	144

List of Figures

Figure 2.1- Traditional animal breeding pyramid structure	31
Figure 3.1- Average genetic gain and inbreeding rate (% per year) over 15 years breeding in early measured trait in sheep using reproductive technologies with and without genomic selection	45
Figure 3.2- Average genetic gain and inbreeding per year over 15 years breeding in late measured trait in sheep using reproductive technologies with and without genomic selection	46
Figure 3.3- Average genetic gain and inbreeding per year over 15 years breeding in early measured trait in beef using reproductive technologies with and without genomic selection	46
Figure 3.4- Average genetic gain and inbreeding per year over 15 years breeding in late measured trait in beef using reproductive technologies with and without genomic selection	47
Figure 3.5- Average genetic gain and inbreeding per year over 15 years breeding in dairy cattle using reproductive technologies with and without genomic selection	47
Figure 4.1- Annual genetic gain and inbreeding increase of Lamb 2020 index for breeding programs. Markers on lines indicate points at which various inbreeding (λ) penalties were imposed	73
Figure 4.2- Annual genetic gain and inbreeding increase of MP+ index for breeding programs. Markers on lines indicate points at which various inbreeding (λ) penalties were imposed.	74
Figure 5.1- Cumulative net present value (CNPV) up to each year represented units of \$1000 over time for Lamb 2020 index breeding program at 1.0% inbreeding per generation in T1 nucleus.....	96
Figure 5.2- Cumulative net present value (CNPV) up to each year represented units of \$1000 over time for MP+ index breeding program at 1.0% inbreeding per generation in T1 nucleus.....	96

List of Tables

Table 3.1- Probability of producing a certain number of live progeny per female per mating for the various reproductive methods and species	41
Table 3.2- Generation interval (L) and annual genetic gain (σ_g) at various increases of inbreeding per generation averaged over 15 years for sheep, beef and dairy traits, respectively	48
Table 3.3- Proportion of selected females assigned type of mating in each breeding program at increase of 1% inbreeding per generation averaged over 15 years for sheep, beef and dairy, respectively	49
Table 3.4- Difference (%) in genetic gain compared to corresponding AI/N breeding programs (Repro) and impact (%) of GS on corresponding breeding programs at various increases of inbreeding per generation averaged over 15 years for sheep, beef and dairy traits, respectively	56
Table 4.1- Lamb 2020 and MP+ index traits, time of trait measurement and genomic selection accuracy.	68
Table 4.2- Probability of producing a certain number of live progeny per female per mating for the various reproductive methods	69
Table 4.3- Annual genetic gain for individual traits, index genetic gain (\$), generation interval (L) at 1% inbreeding increase per generation for Lamb 2020 index	76
Table 4.4- Annual genetic gain for individual traits, index genetic gain (\$), generation interval (L) at varying rates of inbreeding increase per generation for MP+ index	76
Table 4.5- Breakdown of type of matings, number ewes and males for Lamb 2020 and MP+ at 1% inbreeding increase per generation	79
Table 5.1- Annual genetic gain (ΔG) for the Lamb2020 index (in \$ value), generation interval (L), number (n) of female matings per technology, total number of ewes and rams (n) needed to breed 400 <i>nucleus progeny</i> per year when maintaining inbreeding rates to 0.5% and 1.0% per generation. Annual cost of program is measured in units of \$1000.....	89
Table 5.2- Annual genetic gain (ΔG) for the MP+ index (in \$ value), generation interval (L), number (n) of female matings per technology, total number of ewes and rams (n) needed to breed 400 <i>nucleus progeny</i> per year when maintaining inbreeding rates to 0.5% and 1.0% per generation. Annual cost of program is measured in units of \$1000.....	90

Table 5.3- Probability of producing a certain number of live progeny per female per mating for the various reproductive methods, average cost per ewe to apply reproductive technology and average cost per lamb from reproductive technology	90
Table 5.4- Livestock parameters used in simulation	91
Table 5.5- Other breeding program costs (per animal born in T1) for indexes	91
Table 5.6- Income of T1 measured in units of \$1000 dollars derived from numbers of animals sold from T1 to third parties and prices received (\$) per head	94
Table 5.7- Number of rams and ewes per age class as used in T2. All rams used in T2 are born in T1.	95
Table 5.8- T2 income from genetic improvement programs for Lamb 2020 index assuming rams are kept for 3 years of matings. After year 5, formula remains constant.....	95
Table 5.9- Cumulative net present value (CNPV in units of \$1000) at 5, 10 and 20 year intervals, year breeding program breaks even at 0.5% and 1.0% inbreeding increase per generation, respectively	98
Table 5.10- Annual cost of genetic improvement program per T2 ewe, percentage of cost due to: genomic selection (GS), AI, MOET (M), JIVET (J) and phenotyping (Ph); annual income per T2 ewe (I_x /hd) earned in years 5, 10 and 20	102
Table 5.11- $CNPV_{20}$ under different scenarios of price/cost changes (genomic selection decreased to \$10/head; reproductive technologies -RT – reduced by 50%) and index value increase by 25% compared to $CNPV_{20}$ at 1.0% $\Delta F/gen$	104
Table 6.1- Lamb 2020 and MP+ index traits, economic weighting, time of trait measurement and genomic selection accuracy.....	114
Table 6.2- Probability of producing a certain number of live progeny per female per mating for the various reproductive methods	115
Table 6.3- Average cost per lamb as product from type of reproductive technology.....	118

Table 6.4- Proportion of lambs born to reproductive technologies, number dams required to breed 250 lambs, annual genetic gain and average generation interval in respective breeding programs using Lamb2020 index at 1% increase inbreeding per generation.	120
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Table 6.5- Proportion of lambs born to reproductive technologies, number dams required to breed 250 lambs, annual genetic gain and average generation interval in respective breeding programs using MP+ index at 1% increase inbreeding per generation.	121
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