Proc. Assoc. Advmt. Anim. Breed. Genet. 20:94-97

BENEFITS OF MOET AND JIVET IN OPTIMISED SHEEP BREEDING PROGRAMS

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SUMMARY

The additional genetic gain from implementing multiple ovulation and embryo transfer (MOET) and juvenile *in vitro* embryo production and embryo transfer (JIVET) additional to using artificial insemination (AI) and natural mating (N) in sheep breeding programs was assessed. This study was a stochastic simulation and selection based on optimum contributions for varying levels of inbreeding restriction. The genetic gain achieved after 20 years for an AI/N program was 4.89 and 5.16 units of genetic SD (h^2=0.3) when inbreeding was restricted to 1% and 2% per generation, respectively. The additional gain from MOET was 23% and 28% and the additional gain from the addition of JIVET to MOET and AI/N increased genetic gain 60% and 56% for these two levels of inbreeding when compared to AI/N. With the addition of each technology, generation interval decreased, as did the number of breeding ewes.

INTRODUCTION

Artificial insemination (AI) has been used by producers to increase selection intensity in males to increase genetic gain. Further to this, multiple ovulation and embryo transfer (MOET) and juvenile *in vitro* embryo production and embryo transfer (JIVET) are female reproductive technologies that have been employed by sheep producers to increase female selection intensity, decrease generation interval and hence increase genetic gain. There are also some limitations associated with using these technologies. One problem with using JIVET in a breeding program is that selection accuracy is often low when females are selected at a young age. Another problem is that increasing the number of progeny per breeding female can increase the rate of inbreeding significantly (Quinton and Smith 1995). Problems due to inbreeding can potentially offset any additional gains in merit that are associated with using these technologies. Optimal contribution selection principles have been developed to manage the balance between increases in genetic merit while controlling genetic diversity and inbreeding (Wray and Goddard 1994, Meuwissen 1997). Horton (1996) simulated 3% increase in genetic gain with an inbreeding rate of 8% per year in a closed Merino flock implementing AI. Brash *et al.* (1996) showed that in a closed nucleus Merino stud MOET can increase rates of genetic gain by 22% per year. However, these additional gains also resulted in a 50% increase in inbreeding rate.

This paper aims to explore the potential benefit of MOET and JIVET in sheep breeding programs while managing inbreeding. Various levels of inbreeding restrictions will be explored by invoking optimal contributions selection and applying an optimal mixture of matings using AI or natural breeding (AI/N), MOET and JIVET.

METHODS

A closed nucleus breeding program generating 250 progeny per year using a stochastic simulation program was used. Each scenario generated a base population of unrelated animals, and subsequent generations were selected on pedigree-based breeding values. Phenotypes for a single trait were simulated with a heritability of 0.3 and a phenotypic standard deviation of 10. Each year, all animals were assigned breeding values estimated using Best Linear Unbiased Prediction (BLUP).

Optimal selection was used to maximise genetic gain while maintaining genetic diversity. Using Wray and Goddard's (1994) formula, genetic merit (M) was balanced with co-ancestry (C), where, M= x'b, b is a vector of BLUP breeding values and x is a vector of genetic contributions of candidate animals with values in x summing to 0.5 for both males and females. Inbreeding rates were managed by penalizing the average co-ancestry among selected animals; C=λx'Ax, where A is an (n x n) relationship matrix among candidates and λ is the penalty to restrict inbreeding. Price and Storn's (1997) evolutionary algorithm was used to find optimal solutions for M + C. Various values of λ were used to explore a 'frontier' of optimal selection outcomes which resulted in different levels of inbreeding and genetic gain.

In this study, three breeding programs were compared: 1) AI/N mating only, 2) AI/N + MOET and 3) AI/N + MOET + JIVET. In each breeding program AI was used and therefore, depending on the inbreeding restriction, a single male could be assigned to all dams (200+). Females however were limited to just one mating if they were assigned either an AI/N service or if they went into a MOET program. Juvenile females were assigned three matings (due to oocyte numbers recovered and individual oocyte mating ability in IVF process) if they were nominated to be used in the JIVET program only. Males were eligible to enter any breeding programs once they were over a year old. Ewes in AI/N or MOET programs were also only eligible once they were 18 months old. Ewes in the JIVET program were eligible within 3 months of age. If any individuals did not get selected in a breeding program, they were culled. However, in the JIVET program, if a ewe was not selected as a lamb it was again eligible for selection at 18 months of age. All sheep in all programs were culled once they finished five years of life. A mortality rate of 10% was applied each year. The probability of producing a certain number of offspring for AI/N, MOET (Gibbons and Marcella 2011) and JIVET (Armstrong *et al.* 1997) is summarized in Table 1. Each scenario was run for 20 years and replicated 90 times.

Table 1 Probability of producing a certain number of progeny per female per mating for the various reproductive methods.

Progeny	0	1	2	3	4	5	6	7	8	Ave
AI/N	0.1	0.7	0.2							1.1
MOET	0.1	0.05	0.05	0.15	0.25	0.15	0.13	0.07	0.05	4.02
JIVET	0.25	0.05	0.18	0.18	0.1	0.1	0.07	0.04	0.03	8.37*

*predicted average of total progeny of 3 JIVET matings

RESULTS AND DISCUSSION

When inbreeding was unrestricted, the inbreeding coefficient in the AI/N + MOET + JIVET program over 20 years was 165% higher than the maximum inbreeding in both AI/N and AI/N + MOET breeding programs. The maximum genetic gain over the 20 years was also 70% and 40% higher compared to AI/N and AI/N + MOET breeding programs, respectively (Figure 1). This genetic gain and level of inbreeding is considerably less when compared to Pryce *et al.'s* (2010) study where they reached an increase of 231% genetic gain per year and 165% inbreeding per generation in a closed Holstein nucleus. However they used genomic selection in heifers only with no mature cows mated.

There is debate over what the "ideal" amount of inbreeding per generation is and this may vary depending on the species, breed and ability to open the breeding program (Goddard 2009). Responses to the breeding programs were compared under two inbreeding rates: 1% and 2% per generation. Note the number of generations in 20 years (Table 2), and therefore the generation interval differed between the different scenarios.

At inbreeding rates of 1% per generation, JIVET programs can yield up to 60% and 30% more genetic gain than AI/N only and AI/N + MOET breeding programs, respectively (Figure 1, Table 2). At inbreeding levels of 2% per generation, these additional gains are 56% and 29%. However, for double the inbreeding, we see relatively small changes in genetic gain in all scenarios.

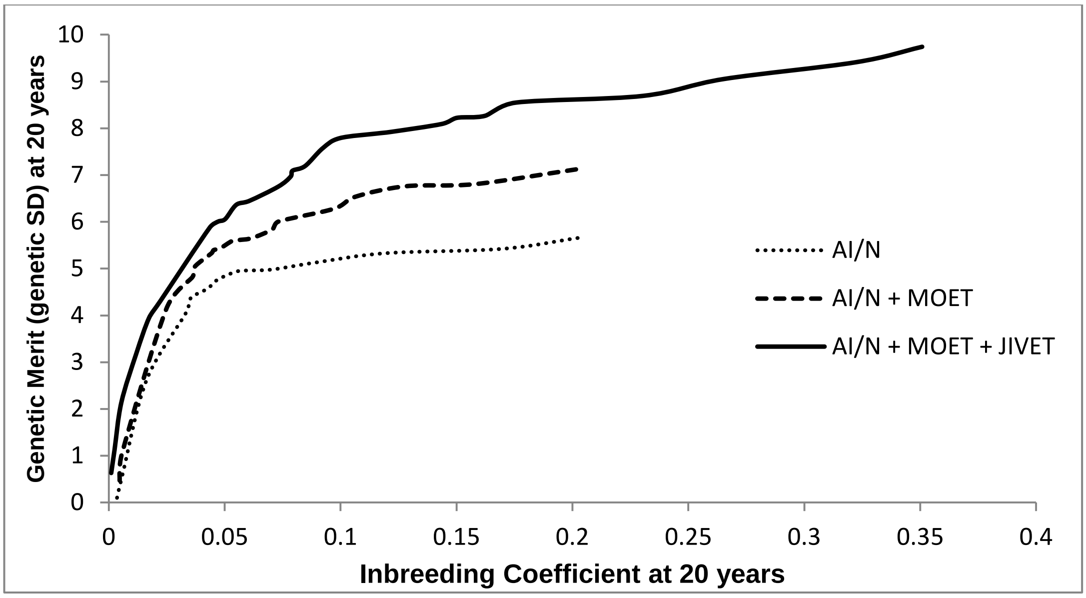

Figure 1 Level of inbreeding with level of genetic gain (in units of genetic SD) in three separate breeding programs.

The AI/N breeding program was used as a base of comparison as in either case ewes would have similar numbers of progeny. Breeding programs with small penalties often only used one or two rams each year which would be deemed not possible when servicing 200+ ewes, hence the reason to switch between natural mating and AI. As the penalty for inbreeding increased so did the number of rams used. MOET breeding programs use considerably less dams than AI/N while the inbreeding rate was not increased. Optimal selection manages to increase selection intensity in females while maintaining diversity, by selecting fewer dams per family rather than selecting fewer families.

An issue from this simulation that needs considering is shortened breeding cycle of ewes who are in JIVET programs. This study assumed all the programs' lambing occurred annually in a seasonal fashion. However further consideration needs to be taken as ewes in JIVET programs are lambing out of seasonal synchrony and generation intervals can be as short as 6 months.

If such short generation intervals were considered, further genetic gain would be expected due to the decreased generation interval. To further increase genetic gain, "age of first mating" could also be decreased for both males and females in AI/N and MOET with 18 months being conservative for a first mating age.

This study did not consider genomic selection. Genomic selection would allow earlier selection of elite juvenile animals because the accuracy of EBVs is higher and increase is relatively highest for young animals that have initially low EBV accuracy. Therefore, the next step in this study is to incorporate genomic EBVs. This would be expected to further increase the benefit of JIVET and

MOET technologies. This study has not factored in costs associated with the reproductive technologies. This will be investigated in further studies in the future.

Table 2 Number of generations (Gens) and ewes (n) used in 20 years at 1% increase in inbreeding per generation (dF), and genetic gain (SD) at 1 and 2% dF

	Gens 1%dF	Ewes	Gain at 1% dF	Gain at 2% dF
AI/N	6.04 ±0.03	235.61 ±1.77	4.89 ±0.03	5.16 ±0.03
AI/N + MOET	7.81 ±0.05	87.96 ±0.94	6.03 ±0.03	6.63 ±0.03
AI/N + MOET + JIVET	10.03 ±0.09	64.68 ±0.24	7.78 ±0.04	8.54 ±0.05

CONCLUSION

Optimal selection techniques used in breeding programs that incorporate female reproductive technologies are shown to increase genetic gain considerably while maintaining acceptable inbreeding levels. The addition of MOET to AI/N breeding programs increased genetic gain and led to shorter intervals. This trend is further increased with the introduction of JIVET. Therefore both MOET and JIVET can contribute significantly to aid in accelerating genetic gain in sheep breeding programs and this benefit is expected to be enhanced by genomic selection.

ACKNOWLEDGEMENTS

The authors would like to thank Andrew Swan for his assistance in developing computer code.

REFERENCES

Armstrong D. T., Kotaras P. J. and Earl C. R. (1997) *Repro. Fert. Devel.* **9**:333.
Brash L. D., Wray N. R. and Goddard M. E. (1996) *J. Anim. Sci.* **62**:241.
Gibbons A. and Marcela C (2011). "Embryo Transfer in Sheep and Goats: A Training Manual." National Institute for Agricultural Technology, Argentina.
Goddard M.E. (2009) In 'Adaptation and Fitness in Animal Populations', pp.41-50, editors J.H.J van der Werf, H.-U. Graser, R. Frankham, C. Gondro, Springer, United Kingdom.
Horton B. (1996) *Aust. J. Exper. Ag.* **36**:249.
Meuwissen T.H.E. (1997) *J. Anim. Sci.* **75**:934.
Nicholas F.W. (1996) *Anim. Repro. Sci.***42**:205.
Price K. and Storn R. (1997) *Dr Dobb's J.* **64**:18.
Wray N.R. and Goddard M.E. (1994) *G.S.E.* **26**:431.