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THE ROLE OF AI IN GENETIC PROGRESS - NEW OPPORTUNITIES FROM NEW TECHNOLOGIES AND NEW APPROACHES

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SUMMARY

Currently, the use of artificial reproductive technologies (ART) in the New Zealand sheep and beef industries is limited. While the past 30 years have seen rapid development of new reproductive technologies and improvements in existing technologies, there are issues in practical implementation. A simple tool like Artificial Insemination (AI) would greatly facilitate and enhance genetic improvement programmes for sheep and beef cattle. Effective application of ART provides an opportunity to increase the rate of dissemination of superior animals and the rate of genetic gain, but there is little evidence to support their practical and economic value in the NZ sheep and beef industries. Complementary technologies such as monitoring the reproductive cycle, estrous synchronization, and semen sexing can improve the efficiency of AI. This paper reviews on-going and recent technological advances that have the potential to significantly improve the genetic merit of sheep flocks and beef herds when implemented as part of ART program.

INTRODUCTION

In the last few decades, a significant improvement in the efficiency of sheep and beef production has been achieved due to implementation of several new or improved technologies and production practices. Major advances in genetics and genomic applications can be expected to further accelerate genetic gain. For example, the rate of genetic gain in the New Zealand sheep flock has increased with the introduction of the Central Progeny Test and SILACE (Amer 2009).

However, there is considerable potential to enhance the rate of dissemination of superior genetic material among breeders, multipliers and commercial flocks and herds, given the availability of a practical and economically-feasible reproductive technology. Artificial insemination (AI) is the technique of choice for widespread dissemination of desirable genetics in farmed livestock.

Currently, the NZ dairy cattle industry is a major user of AI, applying this technology in around 70% of dairy cows (NZ Dairy Statistics, 2011-2012). However very few beef and sheep breeders make use of the technology and application is limited to some breeders producing bulls and rams for sale. The only reproductive technology in widespread use is ultrasound pregnancy scanning. While breeders recognise the potential to enhance the rate of genetic improvement through the use of ART, it seems that both breeders and commercial producers need to be familiar with the opportunities presented by these methods. Artificial insemination, estrous synchronization, embryo transfer, *in vitro* fertilization, and semen sexing are all procedures that have influenced, or can be expected to have a major influence in the beef and sheep industries. The major reason for the slow adoption of technologies such as AI is their relatively high cost in relation to both the risks and the short-term benefits.

In order to assess the opportunities to utilise AI more widely in the NZ sheep industry, it is necessary to define the conditions under which the technology can be expected to operate. The most likely applications will involve AI within the normal breeding season, although there may be some options out of season where problems associated with seasonality can be expected. Aspects to consider include estrous synchronization and the use of frozen, chilled or sexed semen. Therefore this paper highlights some practical aspects of AI in sheep and beef cattle, with an emphasis on the benefits in terms of genetic progress.

ESTROUS SYNCHRONIZATION

Beef cattle. The synchronization of estrous facilitates the application of AI and it may also facilitate better feeding and calving management as all cows will be at the same stage of pregnancy. The extensive nature of cattle production systems makes the use of AI a more challenging option than in the intensively-managed dairy industry (Hall 2011). Ideally, estrous synchronization should be cost-effective, simple and practical to implement, with minimal animal handling and without the need to detect the females on heat (Busch *et al.* 2008). Success with such practices could result in a more highly synchronized and fertile estrous with excellent pregnancy rates from fixed-time AI (FTAI). Currently, several types of GnRH/PGF2α and progesterone/progestin-based estrous synchronization protocols have been developed for use in cattle, allowing farmers to perform timed AI (TAI) without detection of estrous 48 hours after progesterone withdrawal. However there is a need for further development to effectively utilise sex-sorted sperm in association with TAI protocols (Sales *et al.* 2011).

Sheep. Estrous synchronization is fundamental to the application of most ARTs. The most common protocol for sheep estrous synchronization is based on intravaginal devices with progesterone or progestagens for 12-14 days. They can also be combined with equine chorionic gonadotrophin (eCG) to increase ovulatory efficiency and ovulation rate (Letelier *et al.* 2011); this can improve results from FTAI (without estrous detection). Fixed timed AI is usually performed at 48 to 60 hours after progesterone withdrawal, depending on the type of semen (fresh or frozen) and technique used (cervical or laparoscopic). It seems that the time of ovulation is critical for the use of cryopreserved semen in TAI programs. Several studies have sought to improve the time of ovulation especially with the use of sexed semen (de Graaf *et al.* 2007a, 2007b; Beilby *et al.* 2009). Increasing the precision of the time of ovulation using GnRH 36 hours after progesterone/progestagen withdrawal can play an important role in obtaining satisfactory fertility (Hollinshead *et al.* 2002).

ARTIFICIAL INSEMINATION WITH LIQUID STORED SEMEN

The storage of semen can be achieved through methods that reduce the metabolic rate of spermatozoa, thereby prolonging their fertile life. Liquid storage of semen is carried out using temperatures low enough to depress sperm metabolism (5 or 15°C) (Anel *et al.* 2006). Fresh-cooled (15°C) or chilled (5°C) semen is a good alternative to frozen semen, when it is used within a short period after collection. In New Zealand, chilled semen remains the method of choice in dairy cattle, mainly because of restricted seasonal breeding (early September to December) and the development of technology which allows the use of low numbers of sperm, with excellent longevity and viability of sperm during storage and post-insemination (Vishwanath *et al.* 1996).

On the other hand, for sheep, much higher numbers of spermatozoa are required for effective transcervical AI using chilled semen. However lower doses of semen can be used for laparoscopic insemination. An important limitation for the use of chilled semen, especially in sheep, is the logistics of transporting semen given the maximum shelf life of 24 hours with acceptable fertility (Salamon and Maxwell 2000).

ARTIFICIAL INSEMINATION WITH FROZEN SEMEN

The goal of a good sperm freezing protocol is the production of a bank of sperm for AI. However, various biochemical and anatomical compartments in the sperm cells may be altered during freezing and thawing (Amirat *et al.* 2004). Consequently, the fertility is normally lower than that achieved for fresh semen. The most important advantage of frozen-thawed semen is the long-term storage capability. This allows for extensive testing of the processed semen, and is a reliable method for genetic insurance of valuable bulls (Vishwanath and Shannon 2000) and rams.

Due to practicability and a general consistency of results, users in NZ generally have a preference for this type of semen administered by laparoscopic intrauterine insemination. Laparoscopic artificial insemination (LapAI) with frozen semen has been used in the Beef + Lamb NZ Central Progeny Test since 2002. This provides genetic connectedness across years and across the three CPT flocks. In a summary of data for the first six years, McLean *et al*. (2008) reported that the highest conception rate was 83% in 2006.

ARTIFICIAL INSEMINATION WITH SEXED SEMEN

Sex-pre-selection is a potentially attractive technology that could increase uptake of AI in New Zealand. Generally protocols are well-established for sex-sorting of livestock spermatozoa using the Beltsville sperm sexing technology and offspring have been produced in several species by the combination of flow cytometric sperm sorting with a range of ART methods. As with most ART, the practical use of sexed spermatozoa depends on the cost, the fertility results, efficiency and ease of use as assessed against the benefits in terms of genetic gain or the production of a higher proportion of the more valuable sex of offspring.

Furthermore, another limitation from a commercial perspective is the minimum effective dose of sexed semen and the cost of production of the semen. In general, fertility results for beef cattle seem to be lower than with unsorted semen (Seidel, 2011). However the sheep data are relatively good; perhaps surprisingly, low-dose AI of sex-sorted ram sperm has produced similar, if not superior, fertility to non-sorted controls (de Graaf *et al* 2007a, 2007b). A key factor in good results is the time of insemination, which should be close to the time of ovulation. Therefore hormonal protocols to control ovulation, combined with the use of low sperm numbers, provides a highly encouraging outlook for the commercial application of sex-sorted, frozen-thawed ram (Beilby *et al.* 2009) and bull sperm.

Commercial use of sex-sorted sperm depends on its price. It has to be low enough to allow a reasonable profit for farmers. In New Zealand, sexed semen is now being used in dairy cattle, but the cost and possibly slightly lower conception rates are apparently regarded as a deterrent. There is very limited use or beef cattle and there are no indications of any use at all in sheep flocks. However, this technology could be used by breeders and multipliers, allowing more selective production of males and female for replacement and sale.

POTENTIAL BENEFITS OF AI IN GENETIC IMPROVEMENT

The application of ART, such as AI, has had a major impact on the structure of breeding programs, the rate of genetic gain and the dissemination of genetic gain in livestock production (Van Arendonk *et al.* 2011). The industry impact of genetic improvement in the breeder sector is absolutely dependent on the effective dissemination of genetic material from the breeders to the target population (commercial farms). In this situation, AI is very important for effective dissemination.

The major benefit for the NZ beef and sheep industries from the increased adoption of AI is the increase of genetic gain rates (ΔG). To realize this goal it is essential to:

- improve flock (genetic) connectedness across breeder flocks and also with multiplier flocks, in order to generate better estimated breeding values and so better identify superior individuals; and to
- develop better methods to utilize such superior individuals.

Both aspects will be facilitated by increased use of AI (and potentially other ART) in breeding flocks/herds, and in their associated multiplier flocks/herds. In essence, such practices will increase the intensity of selection, which in turn can result in an increase in the average genetic merit of offspring as outlined by Nicholas (1996).

CONCLUSION

Faster and more widespread dissemination of genetic improvement from proven sires in sheep and beef cattle through AI is limited due to a number of factors. These include animal handling and the labour requirement. In cattle, the need for estrous detection or reliable synchronization is a critical issue. In sheep, the insemination technique and consistent conception rates for frozen semen are important aspects to be considered if more widespread of use of AI is to be achieved.

There has been considerable investment in New Zealand in the development and application of genetic technologies. The use of AI and other reproductive technologies has the potential to increase the return on this investment through a greater rate of genetic response, which is also dependent on breeding scheme structure. In this respect, data on the current rate of use of AI and the situations where it is used would be useful to provide a solid base to development of the value proposition for the use of AI (and potentially other artificial breeding technologies). Greater use of AI could be achieved through commitment from organizations in the breeding sector, especially around how to reduce barriers for adoption, together with a clear value proposition of the benefits from genetic improvement and its ultimate impact on farm profitability.

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