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# An economic appraisal of sex-sorted semen in New Zealand dairy herds

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## ABSTRACT

An economic appraisal was undertaken of female enriched dairy semen in New Zealand commercial dairy cattle. Artificial insemination (AI) scenarios were evaluated in cows (C) and yearling heifers (H) with normal (N-) or sex-sorted semen (S-) with a female enrichment ratio leading to 75% (S75) or 90% (S90) heifer calves at birth. In-calf rates with S-semen were 0.75 of normal. Scenarios examined were: cows inseminated with N-semen and yearling heifers naturally mated (CN); cows inseminated with S-semen (CS75 and CS90); cows and yearling heifers inseminated with N-semen (CN-HN); and cows inseminated with N-semen and yearling heifers with S-semen (CN-HS75) and (CN-HS90). These scenarios required 29, 24, 19, 20, 19, and 17 days of AI in cows, respectively. S-semen reduced six-week in-calf rate and final calving rate. The total costs, including reproduction losses, semen and insemination, of producing a four-day old AI heifer replacement calf in a herd of 400 milking cows were $70, $262, $292, $69, $129 and $143. Maximum genetic gain in the milking herd is achieved using S90 semen in the highest genetic merit cows, although this is uneconomic at current semen prices. S-semen has a limited role in New Zealand dairy herds.

**Keywords**: dairy cattle; sex-sorted semen; economics; genetic gain, heifer replacements.

## INTRODUCTION

Controlling the sex of agriculturally important animals may have a significant impact on the economics and genetics of livestock production in New Zealand. Benefits may arise because agriculturally important traits are often expressed to differing degrees in each sex. For example, traits such as milk, eggs and antler velvet are limited to only one sex: Such traits are described as sex-limited traits. In the case of sex-influenced traits such as growth, carcass and survival, both sexes can express the trait but one sex outperforms the other. Sex-linked traits on the other hand are confounded with the X-and Y- chromosome, for example, the Inverdale gene for fecundity in sheep.

In dairy cows in New Zealand, about 50% of the milking herd is required to calve to high genetic merit dairy bulls in order to supply the normal number of high genetic merit heifer replacements. The use of sex-sorted (S-) semen for artificial insemination (AI) with a bias to heifer offspring has the potential to reduce the proportion of the herd used to supply heifer replacements. This has implications not only for the duration of AI within a herd, but for rate of genetic gain where only high genetic merit cows are used to supply replacements. Semen that has been sex-sorted using flow cytometry, is commercially available in New Zealand. The purpose of this paper is to provide an economic appraisal of AI with S-semen when used to provide heifer replacement calves in New Zealand dairy herds.

## MATERIAL AND METHODS

We developed a spreadsheet model of reproductive events in a steady state herd of dairy cows including yearling heifers. The age structure of the herd was determined from published survival rates for cows from one year to the next, using the average survival rates over the last 10 years (Livestock Improvement Corporation, 2011). From this age structure we derived the requirement for four-day-old heifer calf replacements.

The model accounted for submission, conception, final diagnosed in-calf and actual calving rates at each of three or four mating cycles for yearling heifers and cows, respectively. We assumed that reproductive performance in the base herd was above average and therefore a suitable candidate for S-semen. For cows in the base herd, the first cycle 21-day submission rate was 85% and 52% of these cows were pregnant at final diagnosis leading to 44% of the herd pregnant after three weeks. For yearling heifers, the respective figures were 95%, 65% and 62%. The proportion of heifer calves at birth was assumed to be 50%, except where S-semen was used. Heifer calf survival from birth to four-days of age was assumed to be 93% (Pryce *et al*., 2006) and 90% of calves survived from four days of age until yearling heifer mating. The duration of AI was sufficient to provide only for the required number of heifer replacements at four days of age. Natural mating with beef bulls followed the AI period. In the absence of AI, yearling heifers were naturally mated with beef

**TABLE 1**: Duration of AI, 6-week, and final in-calf rates in cows and yearling heifers, and the number of inseminations required to generate a two-year-old in the milking herd following six insemination scenarios. CN = Cows only inseminated with normal semen and no yearling heifer artificial insemination; CS75 =: Cows only inseminated with sex-sorted semen with 75% heifer sex ratio and no yearling heifer artificial insemination; CS90 = Cows only inseminated with sex-sorted semen with 90% heifer sex ratio and no yearling heifer artificial insemination; CN-HN = Cows inseminated with normal semen and yearling heifers inseminated with normal semen; CN-HS75 = Cows inseminated with normal semen and yearling heifers inseminated sex-sorted semen with 75% heifer sex ratio; CN-HS90 = Cows inseminated with normal semen and yearling heifers inseminated sex-sorted semen with 90% heifer sex ratio.

| Reproduction details | Insemination scenario | | | | | |
|---|---|---|---|---|---|---|
| | CN | CS75 | CS90 | CN-HN | CN-HS75 | CN-HS90 |
| Duration of artificial insemination in cows (days) | 29 | 24 | 19 | 20 | 19 | 17 |
| Six-week in-calf rate in cows (%) | 72 | 66 | 66 | 72 | 72 | 72 |
| Six-week in-calf rate in yearling heifers (%) | 85 | 85 | 85 | 85 | 79 | 79 |
| Calving rate in cows (%) | 93 | 92 | 92 | 93 | 93 | 93 |
| Calving rate in yearling heifers (%) | 94 | 94 | 94 | 94 | 92 | 92 |
| Inseminations per two-year-old in milking herd | 5.12 | 4.60 | 3.90 | 5.02 | 4.85 | 4.55 |

**TABLE 2**: Costs ($) associated with inseminations and lower reproductive performance for a herd of 400 milking cows requiring 105 four-day-old heifer replacements, 94 yearling heifers at the start of mating, and 84 two-year-old heifers in milk following with six insemination scenarios. CN = Cows only inseminated with normal semen and no yearling heifer artificial insemination; CS75 =: Cows only inseminated with sex-sorted semen with 75% heifer sex ratio and no yearling heifer artificial insemination; CS90 = Cows only inseminated with sex-sorted semen with 90% heifer sex ratio and no yearling heifer artificial insemination; CN-HN = Cows inseminated with normal semen and yearling heifers inseminated with normal semen; CN-HS75 = Cows inseminated with normal semen and yearling heifers inseminated sex-sorted semen with 75% heifer sex ratio; CN-HS90 = Cows inseminated with normal semen and yearling heifers inseminated sex-sorted semen with 90% heifer sex ratio.

| Item | Insemination scenario | | | | | |
|---|---|---|---|---|---|---|
| | CN | CS75 | CS90 | CN-HN | CN-HS75 | CN-HS90 |
| Yearling heifers | | | | | | |
| Semen costs and insemination fee | | | | 1,537 | 3,375 | 4,995 |
| Cost of lower reproductive performance | | | | | 4,178 | 4,178 |
| Total costs/four-day heifer calf | | | | 60 | 264 | 267 |
| Cows | | | | | | |
| Semen costs and insemination fee | 7,061 | 12,086 | 15,154 | 5,383 | 5,397 | 5,218 |
| Cost of lower reproductive performance | | 14,222 | 14,222 | | | |
| Total costs/four-day heifer calf | 70 | 262 | 292 | 72 | 75 | 79 |
| Yearling heifers and cows | | | | | | |
| Overall total cost/four-day heifer calf | 70 | 262 | 292 | 69 | 129 | 143 |

bulls. For simplicity and in the absence of published reports to the contrary, we assumed that the reproduction outcomes with bulls were no different to those from AI with normal (N-) semen.

We evaluated scenarios in cows (C) and yearling heifers (H) where AI was with N-semen (N) or S-semen (S) with a heifer calf sex ratio of 75% (S75) or 90% (S90). AI in yearling heifers was for one cycle (21 days). In-calf rates to a single insemination with S-semen were assumed to be 0.75 of that achieved with N-semen (Seidel, 2003; Seidel, 2007; DeJarnette *et al*., 2007; DeJarnette *et al*., 2008).

The six scenarios evaluated were:

**Scenario 1**: Cows only inseminated with N-semen and yearling heifers naturally mated (CN).

**Scenario 2**: Cows only inseminated with S-semen with 75% heifer calf sex ratio and yearling heifers naturally mated (CS75).

**Scenario 3**: Cows only inseminated with S-semen with 90% heifer calf sex ratio and yearling heifers naturally mated (CS90).

**Scenario 4**: Cows inseminated with N-semen and yearling heifers inseminated with N-semen (CN-HN).

**Scenario 5**: Cows inseminated with N-semen and yearling heifers inseminated with S-semen with 75% heifer calf sex ratio (CN-HS75).

**Scenario 6**: Cows inseminated with N-semen and yearling heifers inseminated with S-semen with 90% heifer calf sex ratio (CN-HS90).

Given the lower expected in-calf and calving rates following the use of S-semen, we determined the economic cost of reduced six-week in-calf rate and actual calving rate using the valuations and methods from the DairyNZ Incalf programme (DairyNZ, 2007). In brief, a one percentage unit lower six-week in-calf rate or final calving rate was valued at $4 and $10 annual operating profit per cow in the milking herd, respectively. The total cost on a herd basis was obtained by scaling each component to the size of the herd under consideration. Thus, the economic cost of an eight percentage unit lower six-week in-calf rate and three percentage unit lower final calving rate in a 400 cow herd is valued at $24,800 annual operating profit ($4 x 8 x 400 cows plus $10 x 3 x 400 cows).

The cost of N-semen, including the insemination fee, was derived directly from a published pricing list for Livestock Improvement Corporation's Premier Sires daughter-proven semen (Livestock Improvement Corporation, 2009). The unit cost of N-semen is based on a sliding scale with unit cost decreasing as the number of inseminations in a herd increases. Animal Breeding Services Limited, Hamilton New Zealand provided unit prices for S75 ($32) and S90 ($50) semen for up to 100 inseminations, to which an insemination service fee of $5.50 was added. A sliding scale of costs for S-semen including insemination was then derived by maintaining the cost relativity with Premier Sires.

We also examined the economics of yearling heifers as parents in lieu of mixed age milking cows in a single season in order to increase the average genetic merit of replacements. In mid-February 2011 the average genetic merit of all cows in the national milking herd was $57 of breeding worth units (BW) compared with $91 BW for 2009-born yearling heifers, a difference of $34 in BW (New Zealand Animal Evaluation Limited, 2011). The model examined the marginal net present value, assessed through gene flow across five generations whereby a heifer replacement arising from the yearling heifer AI was retained for five lactations. The number of inseminations with N-semen required to generate a two-year-old heifer in milk was 5.02 as derived from the CN-HN scenario in Table 1, and a discount rate of 7% was applied. The age structure of the herd was as described earlier.

This model also examined the economics of the extra genetic gain arising from using S-semen in varying proportions of the highest ranked cows based on BW. The frequency distribution of cows in the national herd in February 2011 (NZ Animal Evaluation Limited, 2011) was consistent with a normal distribution with a mean and standard deviation of 60 and 51 BW units, respectively. We estimated the BW of inseminated cows arising from varying the proportion of total heifer replacements derived from S-semen from 0-100%. Where required to generate the full quota of heifer replacements, cows inseminated with N-semen were assumed to be a random sample of those not inseminated with S-semen. In line with reported practice, we assumed that inseminated cows received 1.3 inseminations (Livestock Improvement Corporation, 2011). The effects of this were a reduction in the proportion of the herd inseminated with S-semen leading to an increase in the proportion of higher BW cows used for AI with S-semen, and thus an increase in the average BW advantage of all cows providing heifer replacements.

## RESULTS

Analysis of the age structure of the herd showed the proportion of two-year-old animals in the milking herd was 20.3% and the proportion of four-day-old heifer calf replacements as a proportion of the milking herd was 25.1%.

Substituting S-semen for N-semen in cows, in the absence of yearling heifer AI, reduced the duration of AI from 29 days to 24 and 19 days, for the CS75 and CS90 scenarios, respectively (Table 1). Inseminating yearling heifers for one cycle with N-semen and cows with N-semen (CN-HN) resulted in a 20 day period of AI in cows. Substituting S-semen for N-semen in yearling heifers reduced the period of AI in cows to 19 and 17 days, for the CN-HS75 and CN-HS90 scenarios, respectively.

Fewer cows inseminated with S-semen were in-calf at six-weeks (66% versus 72%) and fewer finally calved (92% versus 93%, Table 1). Similarly, fewer yearling heifers inseminated with S-semen were in-calf at six-weeks (79% versus 85%) and fewer finally calved (92% versus 94%).

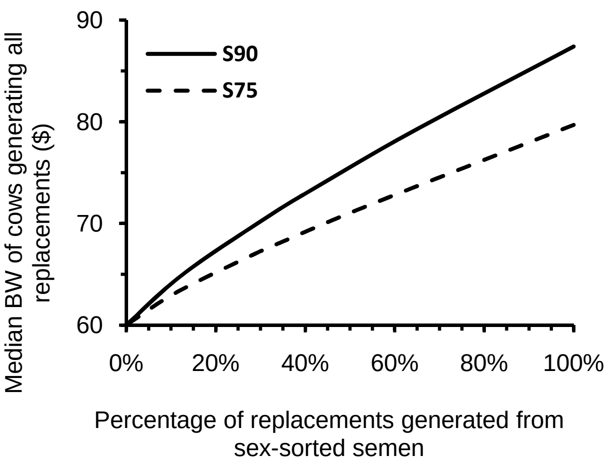
The number of inseminations required to generate a two-year-old in the milking herd ranged from 3.90 to 5.12, with scenarios involving S-semen requiring fewer inseminations (Table 1). The proportion of the total four-day old heifer replacements generated by yearling heifer AI was 25%, 29% and 34% for the CN-HN, CN-HS75 and CN-HS90 scenarios, respectively.

The only costs in the CN and CN-HN scenarios were semen and insemination costs and the total costs per four-day-old replacement heifer calf were similar in the two scenarios for a herd of 400 milking cows ($70 versus $69, Table 2). Although fewer inseminations were required in scenarios involving S-semen, total herd costs were higher due to the higher unit semen and insemination costs, and the costs of lower reproductive performance (Table 2). In scenarios with S-semen not involving yearling AI, the total cost per four-day-old replacement heifer calf was about four fold higher with around 70% of the additional costs due to the lower reproductive performance of S-semen. In scenarios involving yearling heifer AI, the total cost per four-day-old replacement heifer calf was about two-fold higher due to S-semen.

The marginal net present value analysis of the gene flow arising from using yearling heifers as parents in lieu of mixed age milking cows in a single season indicates a breakeven total extra cost of $20 per insemination in 2011 dollars. Thus, provided the additional labour, veterinary, heat synchrony, semen and insemination costs do not exceed $20 per insemination in yearling heifers, an economic margin exists for AI in yearling heifers in the typical herd and retaining their heifer replacements calves. This analysis does not consider potential economic benefits arising from a shorter duration of AI in milking cows.

The highest 60% and 72% of the herd based on BW were required to generate all heifer replacements from S90 and S75 semen, respectively. The median BW of these cows was $87 and $80 if inseminated with S90 or S75 semen, respectively (Figure 1). Reducing the proportion of heifer replacements generated from S-semen reduced median BW until it equated with the national median BW of $60 in the absence of S-semen. AI with S-semen in the top 25% of the milking herd based on BW provides 35-40% of heifer replacements and increases the median BW of all cows generating replacements by about 10 BW units (Figure 1).

**FIGURE 1:** The effect of the percentage of heifer replacements generated from sex-sorted semen with 90% (S90) or 75% (S75) gender purity on the median breeding worth of cows generating all heifer replacements. Assumes 1.3 inseminations per cow inseminated.




The marginal net present value analysis of the gene flow arising from using S-semen exclusively in the highest ranked cows based on BW to generate replacements, in lieu of N-semen in randomly selected cows, indicates a breakeven total additional cost of $14 and $10 per insemination in 2011 dollars for S90 and S75 semen, respectively.

## DISCUSSION

The first key finding from this analysis was that S-semen was considerably more expensive to produce heifer calf replacements, especially when used in cows. Replacement heifer calf costs in cows increased four fold in the absence of yearling heifer AI, and doubled when used in yearling heifers. About 75% of the extra cost was due to the cost of reduced reproductive performance and the balance due to the higher unit cost of semen and inseminations. The DairyNZ Incalf programme valuations of costs of reproductive performance used in the analysis assume a milksolids payment of $5.50 per kg. This may be considered conservative given the current situation and the outlook for global prices.

It is clear that both the unit cost of S-semen and its fertility must be improved for it to be of widespread economic benefit in generating heifer replacements in New Zealand dairy herds. In spite of considerable research on the reproductive impairment impacts of flow cytometric sex-sorting on sperm quality, almost no progress has occurred in cattle. Nevertheless, results in sheep demonstrate that it is possible to reliably achieve at least normal fertility with low dose S-semen and laparoscopic AI (de Graaf *et al*., 2009).

Some of the factors not taken into account in this analysis are the potential benefits arising from a shorter duration of AB of from five to 10 fewer days when cows are inseminated or and nine to 12 days when yearling heifers are inseminated with S-semen. A shorter AI season could have labour utilisation implications during the AI season and potentially during heifer calf rearing because these calves are born over a shorter period. Alternatively, the duration of AB could remain constant and extra heifer replacements generated for selection or sale. Another option is to follow up with beef semen and sell higher value beef cross calves. Analyses of these alternative scenarios are beyond the brief of this paper.

The breakeven total additional cost to undertake yearling heifer AI of $20 per heifer is likely to be exceeded if progesterone-based heat synchronisation is used. Therefore, yearling heifer AI using N-semen is likely to be uneconomic in most herds unless AI is at natural heats and the additional labour and animal handling costs are low compared with the alternative of AI in cows. This conclusion is consistent with the low adoption rate of yearling heifer AI over the last decade with only 100,000 of the approximate 1 million yearling heifers inseminated each year (Livestock Improvement Corporation, 2011).

The second key finding from the analysis was that maximum genetic gain in the cow-to-breed-cow pathway is achieved with S90 semen in the highest genetic merit cows to generate all replacements. In practice, the duration of AI would be extended because it would take most of the breeding season of 10 to 14 weeks for all high-BW cows to naturally submit for AI. Furthermore, the additional cost of S90 semen over N-semen cannot exceed $14 per insemination to breakeven. Generating a lesser proportion of replacements and/or using semen of less than 90% heifer bias results in lower breakeven costs and is therefore less attractive. Current pricing is well in excess of these breakeven costs, and further highlights the need for the development of cost-efficient methods for biasing gender in dairy cattle.

## CONCLUSION

In conclusion, S-semen has a limited role in New Zealand dairy herds in generating heifer replacements and increasing genetic gain until the major reproductive loss and higher semen costs are significantly reduced. Considerably more research is required to deliver these outcomes.

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