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## Simulated impacts of new reproductive technologies on the productivity of beef production systems

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### ABSTRACT

A computer simulation model was developed to explore how new reproductive technologies could improve beef productivity through embryo transfer (ET), sex ratio control and use of small cow breeds pregnant to 'high growth rate' calf genetics. Assumptions were made about conception rates, embryo losses, sex ratios, cow and calf survival, animal weights, and the feed requirements of small and large cows rearing large calves. A range of pregnancy rates from ET (40 to 67%) were assumed compared to natural mating (67%) and it was also assumed that a small cow breed, such as a Jersey, could rear calves to similar weights of those from Hereford x Friesian (H x F) cows. Cow efficiency values were derived as the estimated intake of metabolisable energy by the cow plus calf unit per year per kg of calf weaning weight. The model was based on averages with variance information from fieldwork used for @Risk analyses. In the model, HxF cows subjected to the new technologies such as ET (involving synchronised calving) and sex ratio control were up to 9% more efficient than the 'status quo' mating system. Using a small cow, however, gave gains in efficiency of up to 20%. These benefits were highly dependent on the assumptions used, in particular ET pregnancy rate and cow and calf losses at calving, all of which, singly or together, above threshold values, could destroy the gains or even create losses in efficiency.

**Keywords:** Small cow; large cow; Jersey; Hereford x Friesian; embryo transfer; sex ratio; efficiency; weaning weight, feed intake.

### INTRODUCTION

Beef cows provide major management benefits to sheep and beef farms, besides their direct monetary returns, due to their flexible feed requirements, and contribution to the control of feed quality (McCall, 1994; Nicol & Nicoll, 1987; Pleasants *et al.*, 1994). Their feed flexibility is based around the cow calving in early spring and matching her feed requirements with pasture growth. However, despite recent advances such as selective breeding, yearling mating, use of crossbred dams and high growth rate terminal sires (McMillan & McCall, 1991; Smeaton, 1996) beef cow systems are perceived to be less profitable than other stock classes (Webby & Thomson, 1994) although McRae (1999) suggested his analyses indicated this was not the case. Nevertheless, gains in productivity are highly desirable as all beef production systems struggle to be competitive with other meat proteins such as chicken. In the case of the beef cow, this is mostly due to the relatively high energy cost of maintaining her, per unit of meat output. It amounts to nearly 50% of the total energy cost of the meat produced compared to only 3% in chickens. In addition, markets are increasingly demanding greater consistency, or predictability of product quality and size. Managers of pastoral grazing systems have always had to cope with the impacts of environmental, seasonal and biological effects on animal variation in their production systems (Pleasants *et al.*, 1995). Invariably, strategies to mitigate these effects have a cost either as lower productivity and, or, net returns.

New reproductive technologies (Thompson *et al.*, 1998) have the potential to assist productivity. Opportunities could include beef cow twinning (Graham *et al.*, 1990; Smeaton *et al.*, 1995; Smeaton & Clayton, 1998; Smeaton, 2000), synchronised mating and calving, separation of the genetic link between dam and offspring via embryo transfer (ET), control of progeny sex, control of and consistency of progeny genetics via ET and ultimately by cloning to further minimise genetic variation (Thompson *et al.*, 1998).

Potential benefits tested in this project included:

1. Use of sex ratio to capture faster bull growth relative to heifers, although bulls have slightly lower survival.
2. Use of small, low maintenance, but high milk producing cows to calve, via ET, high growth rate calves.

Both the above incorporated the benefits of calving to a single synchronised mating (Pleasants *et al.*, 1999). In the project, six suckling cow scenarios were modelled. The feed conversion efficiency of these was compared with a designated status quo system of a Hereford x Friesian (HxF) cow naturally mated to a Simmental (S) bull. The comparisons were made over a range of ET pregnancy rates and cow and calf survival rates

### MATERIALS AND METHODS

The seven systems were simulated on an Excel spreadsheet on a mob basis. System 1 involved the current optimum (McMillan, 1989; McMillan & McCall 1991; Smeaton, 1996) of HxF cows naturally mated for three cycles to a finishing sire breed. System 2 involved one cycle only of ET to HxF cows using SxF embryos. System 3 was the same but assumed sex ratio control so that 95% of calves born were male. Systems 4 and 5 were the same as Systems 2 and 3 respectively except that Jersey (J) cows were used instead of HxF. Parallel live weight profiles were used for the 2 breeds, based on a mating live weight of 525kg for mixed age HxF cows and 365kg for mixed age J. Each system involved 100 cows wintered. Systems 2 to 5 achieved all cows pregnant to a single ET mating by "over-mating" with the surplus cows mated elsewhere. Systems 6 and 7 involved 3 cycles of (synchronised) ET mating using the cows 'on-hand', as is the case with natural mating systems. System 6 used mixed sex embryos and System 7 used sex ratio controlled embryos as above. Systems 2 to 7 were tested at a range of ET pregnancy rates and cow and calf survival rates as shown in Table 1.

**TABLE 1:** Key assumptions used in the simulation models

Pregnancy rate after a single mating			
- Natural mate	67 %	Of cows mated	
- ET	40 to 67 %	Of cows mated	
Foetal losses to P.D. in March			
	5 %	Of cows present	
Subsequent foetal losses to calving			
	1 %	Of cows present	
Calf losses at calving			
- Natural mate	4%	Of calves born	
- ET	5 to 15 %	Of calves born	
Calf losses calving to weaning			
	0 %	Of calves born alive	
Relative survival of male to female calves			
	95 %		
Natural mate sex ratio of males			
	51.5 %	relative to total	
Average female calf birth weight			
	35 kg		
Sex effect of male weight			
	115 %	relative to female	
Birth date effect on calf live weight			
	1.1	Kg/calf/day	
Planned start of calving (PSC)			
	1	September	
Period from PSC to weaning			
	180	Days	
Oestrous cycle length			
	21	days	
Cow losses at calving			
- Natural mate	2%	Of cows calving	
- ET	2 to 15%	Of cows calving	

The rationale for the ranges tested were that ET pregnancy rates at present average from 40% upwards and can even vary outside these values (McMillan, 1996; Hasler *et al.*, 1995) but the expectation is that in future, pregnancy rates similar to natural mating should be obtained (Vivanco *unpubl.*). Calf survival at calving was tested over the range 4 to 5% for calves born to HxF cows and 5 to 15% for calves born to J cows. Cow survival at calving was tested at 2 to 4% for HxF and 5 to 15% for J cows based on Baker *et al.* (1990) and limited field observations at Whatawhata Research Centre (Smeaton *unpubl.*). In the models, cow and calf losses were tested as though they were highly correlated; for example, calf losses at 15% were tested only with cow losses of 15%.

Numerous other assumptions were made based on published data (Baker *et al.*, 1990; Morris *et al.*, 1986; Smeaton, 2000; Xu *et al.*, 2000) or measured values (cow and calf weight profiles) from a field project currently running at Whatawhata Research Centre (Smeaton *unpubl.*) and the Reproduction Laboratory, Ruakura Research Centre (likely values of controlled sex ratio, Vivanco *unpubl.*). Table 1 shows the key assumptions used. Both HxF and J cows were assumed to be producing adequate amounts of

fat corrected milk (FCM) to satisfy calf growth requirements. Predictions of metabolisable energy (ME) requirements were derived for the above systems using the functions and information of Geenty & Rattray (1987).

Outputs from the seven systems were expressed as kg calf weaning weight and MJ ME/(cow + calf)/year/kg calf weaning weight.

Statistical outputs were predicted using @Risk (1996). Estimated standard deviations, based on published and field data where available, were used and the model iterated 1000 times through the @Risk programme to provide output standard deviations. Tests of statistical significance were not appropriate, and hence are not reported, because, with a simulation model, it is easy to keep running simulations until any difference is significant. Similarly, standard errors of means can be made arbitrarily small by simulating more samples. Instead, standard deviations associated with the model predictions are presented to give a measure of how much individual simulations vary from the mean predictions.

**RESULTS**

Calf weaning weights generated by the model (Table 2) show the J cows were rearing calves to weights similar to those of the HxF (Systems 2 vs. 4 and 3 vs. 5. This was a predictable outcome given the key assumptions that both the J and HxF produced adequate amounts of FCM milk to satisfy calf growth requirements and that calf birth dates (gestation length), birth weights and live weight gains were assumed to be similar across the 2 dam breeds. Lactation length varied depending on whether the cows were mated for 1 or 3 cycles. This explains the difference of 12kg, between Systems 1 and 2, and most of the difference between 4 and 6, and 5 and 7. In Systems 6 and 7, where three cycles of ET were practised, pregnancy rate affected the numbers of calves born in each cycle. This, in turn, affected average calf age and therefore weaning weight. Sex ratio control was worth 13 to 15 kg in calf weaning weight (Systems 2 versus 3, 4 versus 5 and 6 versus 7).

The efficiency results (Figure 1), show that synchronised (ET) calving and sex ratio control (Systems 2 and 3 versus 1) using HxF cows had a beneficial to neutral effect (9 to 0%) on cow efficiency with the benefits declining as cow and calf losses at calving increased to 5%. That is, ME

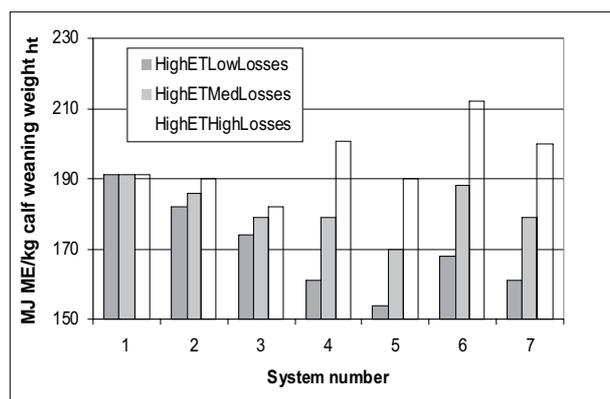
**TABLE 2:** Calf results predicted by the model and key assumptions involved. Coefficients of variation from the @Risk outputs for calf weaning weight ranged from 8 to 13%.

	System						
	1	2	3	4	5	6	7
Cow breed	HxF	HxF	HxF	J	J	J	J
Mating type	NM	1 x ET*	1 x ET	1 x ET	1 x ET	3 x ET	3 x ET
Model outcomes-							
Calf wean weight (kg)	223	231	246	231	246	216-223**	229-236
Age at weaning (days)	170	180	180	180	180	166-172	166-172
<i>Key values affecting the above and which were dependent on assumptions used</i>							
Average calving date	10 Sep	1 Sep	1 Sep	1 Sep	1 Sep	8-15 Sep	8-15 Sep
Calf birth weight (kg)	37.7	37.7	40.0	37.7	40.0	37.7	40.0
No. calves weaned	90	93	91	92	90	72-89	71-87
No. male calves weaned	45	47	87	46	86	36-45	67-83

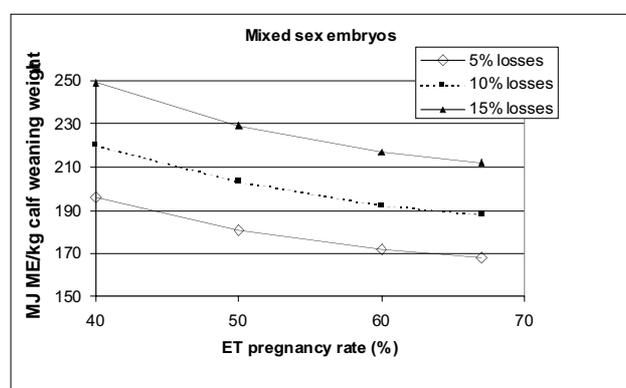
\* 1 (or 3) x ET: 1 or 3 cycles of ET

\*\* Denotes the range of averages achieved, depending on assumptions about ET pregnancy rate and cow and calf losses at calving

**FIGURE 1:** Efficiency values (MJ ME/(cow+calf)/year/kg of calf weaning weight) for each system at an ET pregnancy rate of 67% and low, medium and high cow and calf losses respectively. Coefficients of variation from the @Risk outputs ranged from 9 to 12%.



**FIGURE 2:** Predicted impact of ET pregnancy rate on ME efficiency, at 3 different cow and calf loss rates at calving, for the J cows in System 6. Coefficients of variation from the @Risk outputs ranged from 9 to 12%.



requirements/kg calf weaning weight increased with increasing losses. This was much more graphically demonstrated in the J cows where losses in both cows and calves ranged from 5 to 15%; a much wider range than was tested for the HxF. Where calving losses were low (5%), the J cow was 16 to 20% more efficient (Systems 4 and 5 respectively) than the status quo HxF natural mating system. This was due to the impact of breed differences on cow live weight (Systems 2 and 3 versus 4 and 5 respectively) which in turn affected predicted cow feed requirements. Where losses were high (15% for both J cows and their calves) the benefits were lost.

Pregnancy rates from ET did not affect efficiency in Systems 2 to 5 (Figure 1) because “over-mating”, as described in the Materials and Methods, directly compensated for lower pregnancy rates. This did not apply to Systems 6 and 7. The impacts of different ET fertility rates are illustrated in Figure 2 for System 6.

Given that the efficiency level to break even with System 1 is less than 191 MJ ME/kg calf weaning weight (Figure 1), then Figure 2 shows that System 6, with mixed sex embryos, broke even with System 1 only if ET pregnancy rate was greater than 60% at a 10% loss rate, or 44% at a 5% loss rate. At a cow and calf loss rate at calving of 15%, System 6 never broke even over the range of pregnancy rates tested. When sex ratio control was included (System 7), similar response curves were simulated but the breakeven pregnancy rates were lower at 40 and 50% for calving loss rates of 5 and 10% respectively.

## DISCUSSION

The predictions of models, such as used in this study, are highly dependent on the assumptions of values and variances associated with them. The reported data of Baker *et al.* (1990); Hasler *et al.* (1995); Morris *et al.* (1986); McMillan (1996); Smeaton (2000); Xu *et al.* (2000) and laboratory and field results (Smeaton *unpubl.*; Vivanco *unpubl.*) have provided the basis of the assumptions used in this project. Our preference would have been to use Stockpol (Marshall *et al.*, 1991) to generate the feed requirements of the cows. However, Stockpol is constrained to the point that it cannot simulate cows rearing calves of unlike genetics from such unlike cow weights as those assumed for the J and HxF in this study. Yet early data from the Whatawhata field project (Smeaton *unpubl.*) indicate that these assumptions are appropriate.

The results demonstrated that with HxF cows, synchronised calving (an obligatory or default outcome of ET) and sex ratio control, can both beneficially affect calf weaning weight but are unlikely to have a large impact on beef cow efficiency—at least up to weaning. In addition, both gains are dependent on losses at calving. Although both technologies did each produce 3.5 and 6% bigger calves respectively at weaning, our model predicted an increase in feed consumption by the cow and calf unit, which constrained gains in efficiency. This is typical of the outcome experienced by many breeding systems where selection is based primarily on weight at a given age, e.g. 300-, 500 -and 600-day weight (Dicker & Farquharson, 1994; Graham, 1994; Morris & Cullen, 1995; Morris & Wilton, 1976). Selection usually results in improvement in these weights but in the few cases where feed conversion efficiency has been estimated, efficiency varies little due to the increase in dam size and feed consumption that seems correlated with the above weights at given ages (Smeaton *et al.*, 1999). The exception appears to be the comparison between high vs. moderate milk producing breeds (Ferrell & Jenkins, 1994; Jenkins *et al.*, 1991; Wagner *et al.*, 1986). This effect did not apply in our models.

By far the greatest gains in efficiency were due to the use of a good milk-producing cow of low live weight. However, ET pregnancy rates and loss rates, over the ranges tested, had a major impact on these gains. Minimum ET pregnancy rates and cow and calf loss rates were established from our simulations for the new systems to break even (in terms of energy efficiency) with the status quo of HxF cows naturally mated to a high growth rate finishing sire. Is it possible to capture the potential benefits demonstrated by our models in the real world? Early results from fieldwork (Smeaton *unpubl.*) indicate that J cows may provide opportunities but only if they can deliver their ET calves successfully at parturition.

What has not been established by this study, is the financial impact of the additional cost associated with all the systems simulated, compared to the status quo system. Clearly, these additional costs will raise the minimum performance levels described above. Inclusion of financial analyses is a crucial next step in establishing the place of new reproductive technologies in improving beef productivity.

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