
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

ISSN 0370-2731/2002 *Proceedings of the New Zealand Society of Animal Production 62:* 133-137

Profitability of the use of new reproductive technologies in beef production systems

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ABSTRACT

Improvements in the productivity and profitability of beef breeding cows are highly desirable despite their valuable pasture management role. New reproductive technologies could help. The present work added a gross margin analysis to a previously reported biological model. Technologies, such as embryo transfer, sex ratio control, use of small cow-large calf breeds, were tested. At commodity beef prices, use of the new technologies in beef cows appeared to be mostly uneconomic, even if biological efficiency benefits could be captured, unless embryo prices were unrealistically low. The most profitable outcome was only 11% more profitable than the *status quo* natural-mating system. However, profitability could be greatly enhanced if the returns on weaners born to the new technologies were greater than commodity returns. For example, at a mixed-sex embryo price 'in the straw' of $60 and assuming feed conversion and reproductive efficiency values similar to natural mating, use of embryo transfer broke even at $2.61/kg calf wean weight compared to a commodity return of $1.80. If 'male only' embryos were used, the breakeven return was $2.50. For $40 and $100 embryos, the respective breakeven premiums were 37 and 31% and 62 and 54%. The challenge, therefore, is to locate niche market returns not available to commodity production systems.

Keywords: beef; cow; embryo transfer; sex ratio; efficiency; profitability; breakeven.

INTRODUCTION

Beef cows return major pasture management benefits to sheep and beef farms, besides their direct monetary earnings, due to their flexible feed requirements, and contribution to the control of feed quality (McCall, 1994; Nicol & Nicoll, 1987; Pleasants *et al*., 1994). However, despite recent advances such as selective breeding, yearling mating and crossbreeding (McMillan & McCall, 1991; Smeaton, 1996) beef cow systems are perceived by many to be less profitable than other stock classes (Webby & Thomson, 1994). Gains in both productivity and profitability are highly desirable because all beef production systems struggle to be competitive with other sources of meat protein such as chicken. In addition, markets are increasingly demanding greater consistency, or predictability, of product safety, quality, size, and timing of delivery.

New reproductive technologies described by Thompson *et al*. (1998) have the potential to achieve the above. Possible opportunities include *in vitro* embryo production (IVP), beef cow twinning (Graham *et al.*, 1990; Smeaton *et al*., 1995; Smeaton & Clayton, 1998; Smeaton, 2000), 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). Most of the above incorporate the additional benefits of calving to either single or repeat synchronised matings (Pleasants *et al*., 1999).

These features could yield either gains in feed conversion efficiency, and/or the production of higher value product than that which can be produced by *status quo* mating systems. Higher-value product might be produced through the more efficient or rapid dispersal of valuable genetics, or by the production of niche-market animals, which can only be produced with adequate genetic precision through cloning and ET.

The reproductive technologies in question include harvesting of eggs from abattoir material or by ovum-pick-up (OPU) from donor cows, followed by IVP to produce transferable mixed-sex embryos, sexing and possibly cloning of the embryos and ET of the above embryos into synchronised recipient cows. This paper describes gross margin results from a spreadsheet model, which was used to simulate a range of systems using reproductive technologies. The objective was to determine whether systems using the technologies could be devised that would increase beef production profitability in suckling cattle relative to *status-quo* natural mating systems.

MATERIALS AND METHODS

Description of systems simulated

A gross-margin component was incorporated into the spreadsheet-based simulation model reported by Smeaton (2001). This then provided price sensitivity or break-even information for a range of applications using IVP embryos. Details of the biological model and its assumptions were described by Smeaton (2001). Financial parameters, including enterprise costs, associated mostly with mating and calving, and returns from the sale of weaner calves and cull cows were added. The weaner calf was used as the end point of sale. The cost of the farmer's labour at mating time was not included.

Seven systems (Smeaton, 2000) were simulated on a herd basis, each involving 100 cows wintered. System 1 involved the current natural mating optimum (McMillan, 1989; McMillan & McCall 1991; Smeaton, 1996) of HxF cows mated for three cycles to a finishing sire breed. System 2 involved one cycle only of ET to Hereford x Friesian (HxF) cows using embryos. System 3 was the same as System 2 except that it 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 as a means of increasing biological efficiency due to the lower maintenance requirements of the lighter J cow. Parallel live weight profiles were used for the 2 breeds, based on a mating live weight of 525 and 365kg for mixed-age HxF and J cows respectively.

Systems 2 to 5 assumed all cows pregnant to a single ET mating. This was achieved by “over-mating”, with enough cows being mated elsewhere to ensure 100 cows pregnant to the single cycle of ET mating. Systems 6 and 7 involved three cycles of (synchronised) ET mating using J 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. It was assumed that a single CIDR could be used three times to synchronise three consecutive oestrous cycles if required (W.H. McMillan and W.H. Vivanco *unpublished data.*) without jeopardising existing pregnancies.

Systems 2 and 3 were assumed to produce calf-weaning weights similar to the *status quo* natural mating system. The only way in which these systems could achieve an advantage was from gains due to synchronised calving, sex-ratio control and by producing a higher-value weaner than possible under current systems. In Systems 4 to 7, the J cows were assumed to be producing enough fat-corrected milk (FCM) to produce weaners of similar weight to those in Systems 2 and 3. It was also assumed that they could successfully calve the high-growth-rate calves of Systems 1 to 3.

Other assumptions used and sensitivity analyses

Biological assumptions, described by (Smeaton 2001) were based on published data, observed values in a field project currently running at Whatawhata Research Centre, and from the Reproduction Laboratory at Ruakura Research Centre. Predictions of metabolisable energy (ME) and dry matter (DM) requirements were derived for the above systems using the functions and information of Geenty & Rattray (1987). Outputs from the seven systems were expressed as weight (kg) of calf weaned. Biological efficiency values were expressed as MJ ME or kg DM required by the cow and calf, per year, per kg of calf weaning weight. Systems 2 to 7 were tested over the range of ET pregnancy rates (40 to 67%) and cow and calf survival rates (2 to 15%). Cow and calf losses were tested as though they were highly correlated. This was based on the premise that most cow and calf losses occur at calving time and are due to calving difficulty. In addition, and based on the field trial results at Whatawhata, cow and calf losses for the HxF ET matings and calvings were tested over a narrower range (1 to 5%) than for the J cows (5 to 15%).

Financial assumptions (Table 1) were applied to the above models. A gross margin per 100 cows wintered was derived for each system. The gross margin was then divided by the cost of feeding the particular cow-plus-calf system for a year to produce the figure, cents (c)/kg DM consumed. Sensitivity analyses were carried out by varying the beef schedule or weaner price and also the costs of ET pregnancies; costs of CIDRs, embryos and the ET technician. These were tested along with variations to the biological variables described above (Smeaton, 2001); particularly ET pregnancy rate and cow and calf survival.

TABLE 1: Key financial assumptions used in the gross-margin simulation models.

Item	$/Item
Beef schedule/kg carcass, net of cartage, levies etc	3.80*
Calf weaner value/kg live weight, assuming 50% killing out rate	1.90*
Breeding bull purchase price	2000
Breeding bull selling price	1200
Buy extra cow for mating Systems 2 to 5	750
Sell surplus cow used for mating Systems 2 to 5	700
CIDR	10*
Drugs for ET mating per cow	1
Embryo loaded in semen straw ready for ET	20*
ET technician per cow	10*
Scan or palpate ET cow at day 50 of pregnancy	2
Palpate cow for pregnancy at day 120 to 150	2
Culled empty cow March selling price	550
In-calf cow March purchase price	600
Cost of extra labour/hour at calving if required	15
Cost of extra veterinary time/hour, at calving if needed	100

*These items were varied over the ranges described in the text as part of the sensitivity analyses

Statistical outputs were predicted using @Risk (1996). Tests of statistical significance were not appropriate because, with a simulation model, it is easy to keep running @Risk simulations until even small differences become statistically significant. Instead, coefficients of variation are presented to indicate the variation in each mean prediction.

RESULTS

Sensitivity analyses at equal returns per kg calf weaning weight

Table 2 shows the results for a series of ‘runs’ where, within each run, all seven systems received the same return per kg calf weaning weight.

Within each block of runs (e.g., Runs 1 to 3, Runs 4 to 8 and so on), each system is shown compared to the *status quo* with the comparison made using the gross margin output of c/kg DM. For example, Runs 1 to 3 show the effects of three different weaner calf returns, given low cow and calf losses, hight ET pregnancy rates, and costs for CIDRs, embryos and the ET technician as shown. The bold italic type in Table 2 shows five outcomes in Runs 1 to 3 were more profitable, within that Run, than the *status quo* return. All involved J cows and medium (current) to high calf returns/kg live weight at weaning. Similarly for runs 4 to 8, where a range of embryo prices were tested coupled with low losses, high ET pregnancy rates and calf returns in the mid-range tested, profitability only occurred when embryo prices were $20 (one outcome only, Run 5) or $10 (three outcomes, Run 4); again, with J cows.

Runs 9 to 11 show the impacts of variable ET pregnancy rates, with low losses, calf returns at $1.90, and costs as above. For Systems 2 to 5, in which over-mating was required to achieve all 100 cows calving to a single cycle, low pregnancy rates seriously affected

TABLE 2: Sensitivity analyses, showing gross margin returns in c/kg DM, from a series of runs where the same weaner price/kg live weight was applied within each run but where various changes were made between runs (right hand side of table). Figures in bold italics denote scenarios that were as, or more profitable than *status-quo* natural mating (System 1) within that run. Coefficients of variation of output data ranged from 2-3c/kgD M.

Run No.	H x F nat mate Status quo System 1	HxF ET mixed sex System 2	HxF ET males only System 3	Jersey ET mixed sex System 4	Jersey ET males only System 5	J3Cycle ET mixed sex System 6	J3Cycle ET males only System 7	Assumptions Embryos $	Assumptions Wnr clf $/kgwn wt	J cow losses %	Losses Clf ex J %	ET preg rate %
1	5.8	2.9	3.2	3.6	3.9	4.6	4.9	-20	1	3	4	67
2	11.2	8.5	9.0	10.2	10.8	11.1	***11.6***	-20	1.9	3	4	67
3	17.9	15.3	16.1	***18.3***	***19.2***	***19.0***	***19.9***	-20	3	3	4	67
4	11.2	9.0	9.5	10.7	***11.3***	***11.6***	***12.2***	-10	1.9	3	4	67
5	11.2	8.5	9.0	10.2	10.8	11.1	***11.6***	-20	1.9	3	4	67
6	11.2	8.0	8.6	9.6	10.2	10.5	11.1	-30	1.9	3	4	67
7	11.2	7.6	8.1	9.1	9.7	9.9	10.5	-40	1.9	3	4	67
8	11.2	7.1	7.6	8.6	9.2	9.4	10.0	-50	1.9	3	4	67
9	11.2	8.0	8.5	9.6	10.2	10.9	***11.4***	-20	1.9	3	4	60
10	11.2	7.0	7.5	8.4	9.0	10.6	11.1	-20	1.9	3	4	50
11	11.2	5.5	6.0	6.6	7.2	10.3	10.8	-20	1.9	3	4	40
12	11.2	8.5	9.0	10.2	10.8	11.1	***11.6***	-20	1.9	3	4	67
13	11.2	7.4	7.9	9.1	9.7	10.4	11.0	-20	1.9	5	5	60
14	11.2	4.7	5.3	6.3	6.9	8.6	9.2	-20	1.9	10	10	50
15	11.2	1.4	2.0	2.8	3.5	6.8	7.4	-20	1.9	15	15	40

profitability. For Systems 6 and 7, in which cows were mated to ET for three cycles, high ET pregnancy rates were also essential for profitability (Run 9, System 7) although the impact of lower pregnancy rates was not so great.

Runs 12 to 15 (Table 2) showed that high losses at calving, linked with low ET pregnancy rates, impacted badly on profitability. At low ET pregnancy rates, (Runs 16 to 18 – not shown in Table 2) reducing cow and calf losses on their own was not enough to achieve breakeven with System 1. Even at ET pregnancy rates of 67% and the current calf return of $1.90 (Runs 19 to 21 – not shown in Table 2) profitability was only just achieved in System 7, given the assumed costs and losses $10/CIDR, $20/embryo, $10/cow for the ET technician, and cow and calf losses at calving of 5%).

Control of calf sex ratio generally lifted profitability by 5 to 6%. Cow size, J versus HxF (Systems 2 versus 4 and 3 versus 5) affected profitability by around 20% at the most worthwhile levels of profitability. Bigger *proportionate* gains due to both sex ratio and cow size occurred in some comparisons but only at unrealistically low levels of profitability.

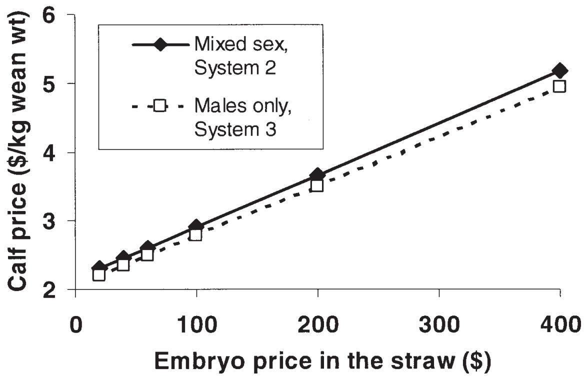
Of the system combinations that were profitable, the margin above the status quo system was small. The most profitable outcome of 19.9 c/kg DM (Run 3) was only 11% more profitable than the status quo. Note that these comparisons all occurred at similar prices per kg calf weaning weight, across systems, within runs.

When systems were compared across runs, a different picture emerged. For example, Systems 2 and 3, Run 3, were 37 and 44% respectively more profitable than System 1, Run 2. This occurred largely because of the difference in returns per kg weaner live weight. Biological efficiency gains had hardly any impact in the comparisons of these systems.

Impacts of 'value-added', on profit from using reproductive technologies.

The results in Table 2 and Figure 1 show that the technologies can be profitable if they can be used in a

FIGURE 1. Calf price required ($/kg wean weight), at the embryo prices shown, for reproductive technologies to breakeven with System 1 and its current returns of $1.80/kg calf wean weight. Coefficients of variation ranged from 10 to 20%.

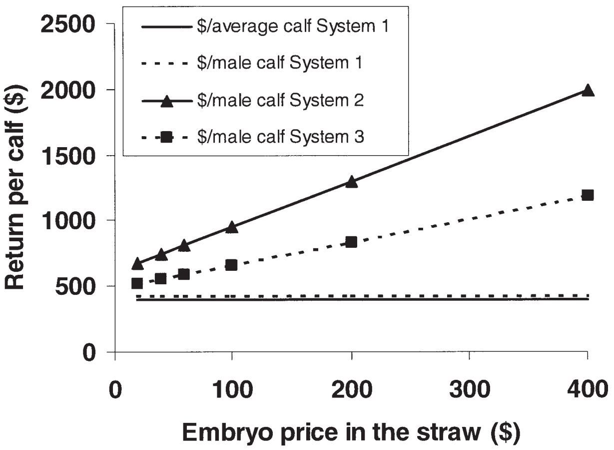


way that improves weaner return/kg live weight relative to *status quo* mating systems. This is best demonstrated by simulation comparisons involving only Systems 1, 2 and 3, in which complications due to cow-size-efficiency effects are absent.

Figure 1 shows the return per kg live weight required for weaners from Systems 2 and 3, over the range of embryo prices shown, to breakeven with System 1 with its weaner return of $1.80/kg live weight. Two separate response lines are shown: System 2, (HxF cow with mixed sex embryos) and System 3, (HxF cow and sex ratio control). These comparisons assumed low losses and high pregnancy rates from the use of the reproductive technologies. In addition, CIDRs and the ET technician were each assumed at $10/embryo.

In Figure 1: at an embryo price of $60, the weaners in the mixed-sex system needed to achieve an average return of $2.61/kg calf weaning weight to breakeven with System 1 at its weaner return of $1.80/kg live weight. If 'male only' embryos were also available at $60, the breakeven return required was lower at $2.50/kg calf weaning weight. This was equivalent to a 45% and 39% price

FIGURE 2. Male calf price required ($/calf), at the embryo prices shown, for reproductive technologies to breakeven with *status-quo* mating (System 1) where returns to female calves were based on $1.80/kg calf wean weight and where biological efficiency gains were nearly absent. Coefficients of variation ranged from 10 to 20%.



premium respectively for mixed-sex and 'male only' embryos over the status quo natural mate calves of System 1. The difference between Systems 2 and 3 was due to combined effects of the faster growth rate of male relative to female calves and the slightly lower survival of males. This outcome again indicates that the returns to sex-ratio control are not great. Figure 2 shows, however, that a different result could occur if male weaners were worth more than females.

In Figure 2: at say $200 per embryo, and where the female calves are sold at schedule prices, the male calves need to earn $835/calf at weaning (System 3) and $1299/calf (System 2) to breakeven with System 1 (where all the weaners sell for the schedule value of $428/weaner or $1.80/kg weaning weight). At $100 per embryo, the required breakeven price/male weaner is $660 and $955 for Systems 3 and 2 respectively.

DISCUSSION

In comparisons of biological efficiency, Smeaton (2001) predicted that significant productivity gains/MJ of ME consumed were possible using new reproductive technologies if high-growth-rate calves were placed by ET into small cows. In large cows, productivity gains were small. The present results show that when financial assumptions were included, profitability of the efficient systems was only greater than the *status quo* system of natural mating when the technologies could be used at relatively low cost, high pregnancy rates and low losses. These performance requirements are not being achieved at present (W. H. Vivanco *personal communication*). At commodity beef prices, therefore, use of the technologies in beef cows appears likely to be uneconomic, even if efficiencies can be captured successfully by using small cows, unless embryo prices are low.

However, the results have demonstrated that profitability from the use of reproductive technologies could be greatly enhanced if the returns on weaners so born were greater than returns on calves from *status-quo*-mating systems. The challenge, therefore, is to find beef products that are unique or special, which have higher returns than are available from commodity production systems and which are not easily produced by these conventional systems. Special, recessive, genetic characteristics that are expressed only in animals homozygous for the gene could fall into the special product category. Other animal products, for very specific markets, which require very low variation, would be another example – if they could be produced only by using reproductive technologies. Seed stock two-year breeding bulls, which sell for considerably more than their schedule price, are a third example. Finally, these technologies could play a major role in rapidly propagating valuable new genes out to the industry. In a similar bioeconomic evaluation in the United States, Ruvuna *et al.*, (1992b) concluded that using embryo lines to produce herd bulls may be viable for commercial beef production, if embryos of appropriate genetic potential can be identified. However, in their models, they set the costs of the embryo, sexing and implantation to zero and did not publish the breakeven values of these items.

There are some important questions still to be answered in the use of the reproductive technologies described. (1) What are the limitations to the use of disproportionately sized embryo and recipient cow breeds? Ruvuna *et al.*, (1992a) established that matching these two items has a strong influence on net returns although this was not examined in the present study. (2) What are the likely prices of embryos arising out of the two embryo-production pathways outlined earlier? Relative to the size of dairying's artificial breeding industry (Anon 2000), the ET industry is small. Presumably, few economies of scale apply at present. Cost reductions and increases in ET pregnancy rates and calving efficiency, which appear unachievable at present, may well be possible in the future. (3) What will be farmer and consumer reaction to the technologies and how will farmers react to the increased risk, planning, labour, and mental energy required to use them? The financial benefits will have to be substantial to outweigh these aspects and returns will need to be considerably greater than breakeven.

ACKNOWLEDGEMENTS

This project was funded by contributions from Meat NZ and FRST.

The authors also wish to thank all science peers who provided critical commentary along with those staff involved with related research at both Whatawhata and Ruakura Research Centres. Specific thanks also goes to Simon Woodward and Neil Cox for assistance with spreadsheet and macro programme construction.

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