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

Current and emerging reproductive technologies for beef breeding cows

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ABSTRACT

Reproductive technologies may be defined as any technology which impacts on the reproductive potential of the herd. Reproductive technologies applicable to beef breeding cows can broadly be classified into those requiring either a low, medium or high technical input. The examples of 'Low Technology' options discussed are: age at first joining, breed/cross or strain of cow, time of calving, and pregnancy diagnosis. In traditional breeding cow herds, cow productivity can be increased by modest amounts (5-10%) if only single-option 'low tech' changes are implemented. However, these fundamental technologies need to be well developed before higher technologies can be successfully applied. Two examples of 'Medium Technology' strategies that have been available for some time include oestrous synchronisation and multiple suckling. Oestrous synchronisation has the potential to facilitate an increase in the number of herds adopting yearling heifer mating. Twin suckling through fostering an additional calf has been demonstrated to significantly increase the number of calves weaned per cow. Emerging 'High Technology' options include: twinning, controlling the sex of calves at conception and cloning. Future developments in embryo technologies are vital in many of the emerging reproductive technologies for beef cows.

Keywords: breeding cows, reproduction, cow efficiency, reproductive technology, oestrous synchronisation, twinning.

INTRODUCTION

The primary purpose of beef breeding cows in New Zealand is to annually wean a calf of high weight. It is therefore fundamental that the reproductive management of the cow herd and the resulting level of reproductive efficiency is of critical importance. Furthermore, management factors that impact on reproductive performance often also impact on calf growth. As a result of this confounding, it is useful to give consideration to both the numbers of calves as well as the weight of calf produced by breeding cows. Accordingly, a very broad definition of reproductive technology has therefor been adopted to provide scope in addressing the issues. The purpose of this paper is to discuss the role of current and emerging reproductive technologies in beef breeding cows herds in New Zealand.

DEFINITION OF REPRODUCTIVE TECHNOLOGY

Reproductive technology has been defined as any technology that impacts on the reproductive performance of an individual breeding cow or a herd of breeding cows. This definition includes technologies which impact on the number of calves produced as well as the weight of calves at weaning time. Current and emerging reproductive technologies cover the spectrum of options from low to high risk, low to high cost, and from low to high technical input. Reproductive technologies can impact on cows or on herds in a variety of ways. They have the potential to improve calf productivity, improve herd management, and to improve genetic gain. Most, if not all of the technologies, have direct application in the dairy herd. In fact, technologies and concepts relevant to beef breeding cows are often first developed and established in the dairy herd.

WHAT REPRODUCTIVE TECHNOLOGIES ARE AVAILABLE NOW OR IN THE NEAR FUTURE?

Many previous reports on reproductive technologies have focused on what may be termed 'physiological' technologies (eg AI, embryo transfer etc.). The approach adopted in this paper is to examine 'management' as well as 'physiological' technologies, so as to provide a wider perspective. Rather than discuss all of the available and emerging technologies listed in Table 1, a sample of 11 technologies have been chosen to illustrate the potential contributions of some of the technologies.

Accordingly, examples of technologies which have a low technical content ('Low Technology'), a medium technical content ('Medium Technology') or a high technical content ('High Technology') are discussed.

'Low Technology' Options

'Low Technology' options may broadly be classified as 'management' technologies (Table 1). Compared with other technologies to be discussed, they tend to be characterised by low cost, low risk and low return. For example, a recent series of papers has compared beef breeding herd performance for a range of these reproductive technology options (McMillan and McCall, 1991 and McMillan *et al.*, 1992 a, b). The options discussed in the current paper include: age at first joining (specifically yearling heifer mating), breed of beef cow (traditional and beef x dairy), growth-selected breeding cows (Angus), time of calving (late winter and early spring), and pregnancy diagnosis and foetal ageing. The advantages for some of the technologies are discussed in relation to per head performance as well as on the basis of feed requirements (loosely termed per ha performance).

Yearling heifer mating: Yearling heifer mating and therefore calving first at 2 years of age has long been advocated as a

TABLE 1: Reproductive technologies for beef breeding herds.

Technology	Target Sex	Technical Level	State of knowledge	Cost	Level of risk	Nature of benefit*
Age at 1st Joining	Both	Low	High	Minimal	Low	P, G
AI	Cow	Moderate	High	Low	Low	P, G
Breed	Both	Low	Moderate	Moderate	Moderate	P,G,M
Serving capacity	Bulls	Moderate	Moderate	Low	Low	P, G?
Breeding soundness	Bulls	Moderate	Moderate	Low	Low	P,G?
Cloning	Both	High	Low	High	High	P,G,M
Bull ratio	Both	Low	Moderate	Low	Low	P,G
Early puberty	Both	Low	High	Moderate	Low	P,G
ET	Cow	High	High	High	Moderate	P,G
Heat detection	Cow	Moderate	High	Low	Low	P,G,M
Immunocastration	Both	Moderate	Low	Moderate?	High	M?
Calving season	Cow	Low	High	Low	Low	P,M
Multiple suckling	Cow	Moderate	High	Moderate	Moderate	P
Oestrous synchronisation	Cow	Moderate	High	High	Moderate	P, G, M
Pregnancy diagnosis	Cow	Moderate	High	Low	Low	P,M
Pregnancy enhancers	Cow	High	Low	?	?	P,G,M
Sex ratio	Both	?	Low	High?	High?	P
Slow release sperm	Cow	Moderate	Low	?	?	P,G
Superovulation	Cow	High	High	High	High	P,G
Twinning	Cow	High	Moderate	High?	High?	P,G,M

* P – production, G – genetic, M – management

means of increasing the number of calves weaned per head (Carter and Cox, 1973; Smeaton and Winn, 1981; Morris, 1982).

While the evidence is consistently in favour of yearling heifer mating as a reproductive strategy to increase per head performance, the evidence is sometimes less convincing when account is taken of the additional herd feed cost to achieve this. For example, it has been shown that in some situations Angus yearling heifer in-calf rates of about 70% are required to equate in efficiency with a herd in which first mating is delayed until 2.25 years of age (ie '2'-year-old first mating) (McMillan and McCall, 1991). In contrast, yearling heifer in-calf rates of only 40% are required for beef x dairy breeds (McMillan and McCall, 1991), or in some other Angus herds (eg, McMillan *et al.*, 1992 b). Yearling heifer mating may not therefore be as worthwhile a reproductive option in traditional beef breeds, unless high (>85%) in-calf rates can be achieved. In practice, it is generally difficult to achieve this high level of performance when using a restricted mating period of 5-6 weeks (Smeaton and Winn, 1981).

However, the important point is that yearling heifer mating can be worthwhile (5-10% more weight of calf/unit feed, McMillan and McCall, 1991; McMillan *et al.*, 1992 b) in any breed of beef cow, provided in-calf rates at 2-year-old re-breeding are *no worse* than achieved at the yearling mating (McMillan *et al.*, 1992 b). The economic advantage may be of the order of only \$5-\$15/cow in the herd (inclusive of heifer replacements) using prevailing weaner calf prices, even though 5-10% fewer cows and replacements can be grazed on the same feed when yearling heifer mating is adopted (McMillan and McCall, 1991).

Traditional and beef x dairy breeding cows: The per head calving performance of Angus cows from 3 years of age can be slightly higher than Hereford x Friesian cows (90 vs 88%, McCall *et al.*, 1987; see also Morris *et al.*, 1993). Thus, for number of calves *born* per cow, Angus cows aged 3 years and older may be a better choice compared with Hereford x Friesians of the same age. But, a similar number of calves may be *weaned* from Angus compared with Hereford x Friesian cows aged 3 years, since calf survival is often lower in calves born to Angus cows (92 vs 96%, McCall *et al.*, 1987),. These results indicate that differences in calf weaning percentage between traditional and dairy x breeds are probably small (if yearling heifer mating is not carried out) and should not be the major factor in changing breeds. When the advantage of faster growing calves born to beef x dairy cows are taken into account, the crossbred may be preferred to traditional breeds. The main point illustrated is that some breeds excel for some traits but not others, and it is therefor important to clearly define the important traits.

If consideration is given to herd (including heifer replacements) feed cost differences between breeds, then Angus cows wean 5-10% more calves per unit of feed, compared with Hereford x Friesian cows (McMillan and McCall, 1991). But when breed of cow differences in calf weaning weight are also taken into account (15-20% in favour of beef x dairy cows, McCall *et al.*, 1987; Baker *et al.*, 1991), beef x dairy herds produce 10-15% more weight of calf per unit of feed (McMillan and McCall, 1991). The economic advantage may be of the order of \$40-\$60/cow (including replacements) using prevailing weaner calf prices, even though 10-20% fewer Friesian cross beef cow can be run for the same feed cost.

Growth-selected breeding cows: With a trend amongst some bull breeders to favour overseas bulls with high growth rate genetics (eg some American Angus and Hereford bulls), it is worthwhile to consider some of the likely implications of genetically large strains on reproductive performance in the beef breeding herd. The best NZ data set comes from a herd of Angus cows where selection has been based on yearling weight for over 20 years (Baker at al., 1991 b). On average, cows in the selected herd were 10% heavier than their unselected counterparts (McMillan *et al.*, 1992 b). On a per head basis, slightly more calves were weaned in the selected herd (75 vs 72%, McMillan *et al.*, 1992 b). In contrast, when consideration was taken of feed costs, 5% fewer calves were weaned from the selected strain of cows, although the calves were about 10% heavier at weaning. The net result was a similar output of calf weaning weight from the growth-selected and unselected herd. Collectively, these findings suggest that selection for early growth performance in cattle is unlikely to change reproductive output on a per head basis, but that fewer calves are likely to be weaned when some of the additional feed costs of larger cows are taken into account. The net effect is a similar total weight of calf weaned per unit of feed required. However, if a 10% premium exists for heavier weaner calves (in $/kg weaning weight), then the gross economic advantage to the growth-selected herd is about $20/cow (including replacement heifers). Until weaner calf sales are conducted on a live weight basis, these premiums may not be realised.

Time of Calving: The choice of calving date can have important effects on some reproductive parameters. In particular, a mean calving date in early September rather than early October can lead to longer intervals to first post calving oestrus (71 vs 55 d, Smeaton *et al.*, 1986). However, this did not translate into a longer interval to conception (84 d both groups), although pregnancy rates were lower in early calving cows (87 vs 92%). In the modelling study on time of calving effects (McMillan and McCall, 1992) it was assumed that time of calving had no effect on pregnancy rates (rather than a 5% penalty for early calving), as cows were assumed to have achieved the same live weight at calving. If this 5% reproductive penalty is applied to early calving cows, then for the same feed cost, only 80% as many calves are weaned from an early calving herd. However, because early-born calves are older and therefor heavier at weaning on a given date, calf output is likely to be 5-10% lower in earlier calving herds. Collectively, these data suggest that provided calving to first oestrus intervals are not prolonged (ie > 70 days on average), there may be little need to alter mean calving date for a herd.

Pregnancy Diagnosis and Foetal Calf Ageing: Pregnancy diagnosis allows a herd owner to identify which cows are pregnant and which will not calve. As a consequence, the owner has the option of managing these 2 groups of cows differently. Foetal calf ageing, often into early, mid or late (or just early and late) calving cows allows these sub-herds to managed differently, especially in late pregnancy. Some applications and benefits of pregnancy diagnosis and foetal calf ageing are shown in Table 2. The benefits, which have been estimated under Australian conditions, appear to be very large.

According to the Australian analysis, about $75/cow can accrue to using information from applying pregnancy diagnosis/ foetal calf ageing techniques. About $28 of this arises because non-pregnant cows are culled and are either replaced with pregnant cows, or the remaining cows are given a smaller total amount of feed. Under NZ conditions, the direct benefit from selling non-pregnant cows and heifers is 5-10% more calf production from a fixed amount of feed (McMillan and McCall, 1992). The financial benefit in a 100 cow herd is thus about $25/cow, about the same advantage estimated in the Australian study. Foetal calf ageing was estimated to return about $47/cow. About one third of this was due to 'anticipating' that some calf deaths would occur and that cows with live calves would replace these. Another quarter of the benefit was due to the more appropriate feeding of early and late calving cows and thereby increasing subsequent reproductive performance. The balance of the benefit of foetal

TABLE 2: Potential use and financial benefits of pregnancy diagnosis and foetal ageing technology in a 100 cow beef breeding herd (From M Blockey, 1993).

Use	Benefit ($NZ)	Achieved by:
To detect the 10% or so non-pregnant cows	$2750	Replacing non-pregnant cows with pregnant cows
Foetal ageing to 'anticipate' calf losses	$1500	Replacing non-lactating cows with lactating cows and there calves
Foetal ageing to 'converting' late calving cows into subsequent early calving cows	$1125	Better feeding with the result that 4% more weaner output is produced
Foetal ageing to identify early-calving heifer replacements	$2125	Early calving heifers out produce later calving heifers
Overall	$7500	

calf ageing was attributed to the higher lifetime performance from retained heifer calves which were born to early rather than late calving cows.

It is difficult to estimate the likely financial benefits due to foetal calf ageing under New Zealand conditions especially under restricted joining duration (6-8 weeks). However, it is likely that they are considerably lower than the Australian estimates where the herd was joined with the bull for an extended period (ie 12 weeks).

'Medium Technology' Options

Two examples of 'Medium Technology' options are discussed, namely oestrous synchronisation and fostering (multiple suckling). Oestrous synchronisation is examined as a technology to facilitate the adoption of yearling heifer mating.

Oestrous Synchronisation: The synchronisation of oestrous activity is a reproductive technology that facilitates the application of AI and embryo transfer. In addition, it may facilitate appropriate feeding and calving management since batches of cows will be at the same stage of pregnancy. The economic effect of oestrous synchronisation in beef heifers on average weaning weight of calves has been reported under US conditions (Gaines *et al.*, 1993). The financial benefit in the US study was such that for every $1 invested in synchronisation chemicals, the return in extra calf weaning weight was worth about $2. The benefits were deemed to arise simply from having earlier born, and therefore heavier calves at weaning in the synchronised heifers. Other possible benefits that may have arisen from a more appropriate feeding of pregnant heifers were not examined in the US study. In particular, the possibility of an earlier return to oestrus post-calving and the potential for higher fertility in the earlier calving treated heifers warrants investigation.

To examine some of these considerations under NZ conditions, a cost benefit analysis of oestrous synchronisation in yearling heifers was undertaken using a CIDR® synchrony system. The planned start to calving was assumed to be the same for a 'typical' and a synchronised herd and 85% of heifers were in-calf in both groups. In both cases, 2 'cycles' of mating were used although the duration of mating was 42 d and only 23 days respectively. Clearly, one of the benefits of synchronisation is that the effective mating period is considerably shorter. The distribution of calving dates in the 2 groups of heifers in illustrated in Figures 1 and 2. The major feature of the calving distributions is the earlier median calving date (by about 10 d) in the synchronised heifers. The effect of this earlier calving date on weaning weight is 12 kg (179 vs 167 kg) heavier calves at weaning (Figures 3 and 4). When the likely carryover effect of an earlier calving date in synchronised 2-year-old heifers on the median calving date as 3-year-old cows was examined, none were found.

FIGURE 1: Distribution of calving dates in heifers following natural oestrus and 2 'cycles' of mating.

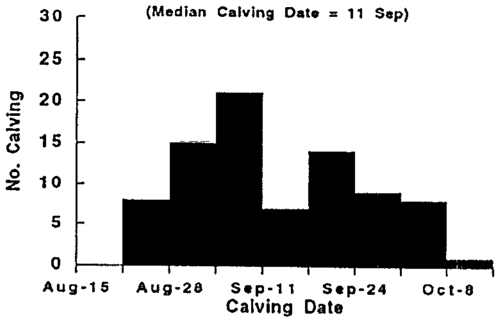


FIGURE 2: Distribution of calving dates in heifers following synchronised oestrus and 2 'cycles' of mating.

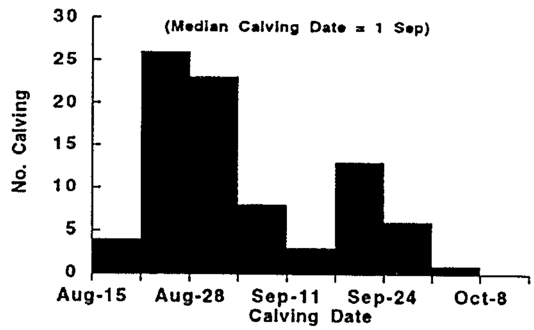
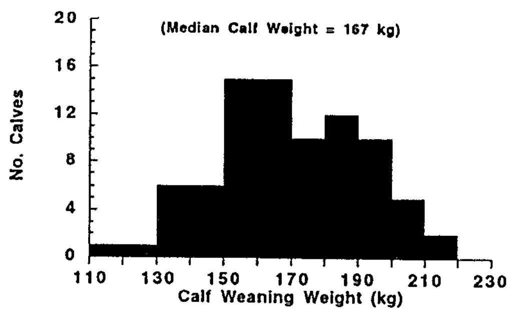
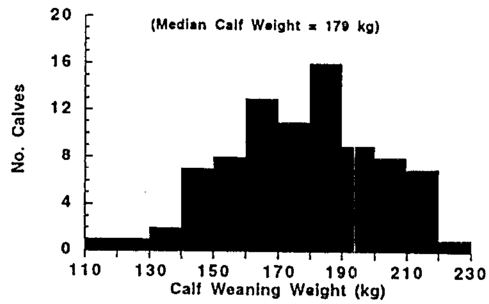


FIGURE 3: Distribution of calf weaning weights in heifers following natural oestrus and 2 'cycles' of mating.



The important conclusion from this analysis is that the production benefits when applying synchronisation treatments are unlikely to persist beyond that particular crop of heifers and calves. Furthermore, the weaning weight advantage of calves in the synchronised group is unlikely to persist until slaughter because of the low correlation between calf weaning weight and later weights (Baker *et al.*, 1974). Since

FIGURE 4: Distribution of calf weaning weights in heifers following synchronised oestrus and 2 'cycles' of mating.



the actual financial cost of the synchrony treatment is about the same as the financial benefit from heavier calves, it is clear that other benefits are needed to increase the appeal of this technique. If the application of synchrony treatments has other management benefits (eg easier feeding and calving management in 2-year-old heifers), some producers may find it a useful technique to facilitate the adoption of yearling heifer mating. The extra benefit from oestrous synchronisation/yearling heifer mating may therefore be up to $15/cow.

Multiple suckling using an additional foster calf: The rearing of one or more additional calves by cows naturally rearing their own single calf has long been recognised as a means of increasing reproductive efficiency. Twin-/multiple-suckling trials have been reported under pasture grazing in Ireland (Drennan, 1971; Nicoll, 1982), Australia (Rowan and Wall, 1970), France (Petit *et al.*, 1978) and New Zealand (Everitt and Phillips, 1971; McMillan *et al.*, 1993).

A major finding in the latter study, using a 'dog-collar' method to facilitate fostering, was that a single-born calf reared by its own dam as a co-twin to a foster calf had a weaning weight similar to a contemporary single-born and single-reared calf. Thus, the extra calf output from a twin-suckling system based on fostering one calf was largely a function of the growth performance of the foster calf. The calves fostered onto beef x dairy cows may grow more slowly to weaning compared with either the cow's own calf reared as co-twins to a foster calf or a calf reared as a single. In spite of this, up to 80% more calf weaning weight can be produced with fostering technology (McMillan and Evans, 1993). Neither cow live weight nor reproductive performance appear to be significantly reduced by rearing two calves. Collectively, these results indicate that considerable potential exists to increase calf output using simple fostering technology.

'High Technology' Options

The future impact of many of the reproductive technologies in this category on livestock production in New Zealand have recently been reviewed (Baker *et al.*, 1990; Tervit *et al.*, 1990; Macmillan and Tervit, 1990). In this section twinning, sexing and cloning technologies are examined.

Twin Pregnancies: Twinning affords the opportunity to increase the number of calves weaned and thereby increase the total weight of calf weaned per cow. Furthermore, twinning can improve the net economic return from beef herds by about 20% (Herd *et al.*, 1993). Should sex-control technology become financially viable, then twinning in conjunction with sex-control could increase net economic return by about

35%. It is unlikely that other options exist to achieve such large potential gains in biological efficiency in beef cows.

The normal twinning rate in beef cow herds is 0-5% (Morris, 1984). After one round (ie 1 cycle) of natural mating in a well managed herd of 100 beef cows, about 60 calves are expected at term. With induced twinning, using either two transferred embryos or one 'native' embryo with one transferred embryo, about 96 calves are born from one 'round' of transfer (range between studies 64-101, Table 3).

The proportion of cows with either 0, 1 or 2 calves at term after one round of transfer is about 33% in each case. Thus, about half of the pregnant cows will give birth to twins. With a second round of induced twinning in cows which return to oestrus after a first round of induced twinning, it is possible that another 20-30 calves would be born in a herd of 100 beef cows, to give a total crop of about 120 calves born. In comparison, about 80 calves would be expected after 2 rounds of natural mating. In reality, a number of combinations of induced twinning and natural mating could be used to increase the calf crop. It could be possible with current technology to produce a total of about 140 calves born in a 100 cow herd using 3 rounds of induced twinning compared with about 90 calves born with natural mating. Further increases in calf crop following induced twinning are unlikely until the survival rate of transferred embryos are increased. Because 2 embryos are transferred, an increase in survival rate of 10 percentage units will increase the calf crop by 20 percentage units following one round of twin embryo transfer.

Changing the Sex Ratio at Birth: Controlling the sex of calves may have a significant impact on the economics and genetics of livestock production in New Zealand. For example, by changing the ratio to more bull calves (and therefore fewer heifer calves) at birth, the aim is to capitalise on any natural performance advantages of bull calves compared with heifer calves for meat production. On the other hand, there may be some production disadvantages associated with bull compared with heifer calves. Both factors need to be considered in any analysis of bull compared with heifer calves.

Using NZ data, it has been shown that if only bull calves are born, then weaner calf production is increased by about 2% on average (range -3 to 5%, McMillan, 1993). The heavier weaning weight of bull calves (by 10-20 kg)barely compensates for the fact that fewer bull calves survive to weaning (by 3-6%). However, if a 10-20% financial premium (in $/kg) exists for bull calves compared with heifer calves at weaning time, then the gross financial return can be about 10% higher. In dollar terms, this suggests a break-even price per pregnant cow of $25-30 can be paid for cows pregnant with bull calves compared with cows pregnant with calves of unknown but mixed sex. Put another way, cows with bull calf pregnancies may be worth, at most, $50-60 more than cows pregnant with heifer calves, if weaner calves are sold.

Technology to pre-arrange sex of calves prior to birth on a large scale are not presently available. The most promising development is sperm sorting, although the inability to accrue large numbers of sorted sperm in a short time precludes standard artificial insemination (Johnson *et al.*, 1994; Cran *et al.*, 1994). Embryo sexing techniques have been available for some time but they do not pre-determine the outcome of conception in the manner possible with sorted sperm.

Cloning: In simple terms cloning is the production of genetically identical individuals. Natural identical (ie monozygotic) twinning, arising as a result of embryos splitting into two, is an example of cloning. The natural rate of production of such clones is very low and has been estimated at from 1 to 4 per 1000 births in cattle (Johansson *et al.*, 1974).

Artificial cloning technology simply aims to increase the numbers of genetically identical offspring from a common source. Artificial embryo splitting is one means of cloning (eg Lewis, 1994). Prior to producing large numbers of clones, it is clearly desirable that the genetic quality of the clones are proven. Thus, maternal clones that exhibit superior maternal traits (eg puberty, fertility, calving ease, milk production, post-partum rebreeding, etc) could have large and important benefits in herds of beef breeding cows. In addition, clones that excel in growth and carcass traits (terminal clones) could be produced. It is not difficult to envisage the scenario in New Zealand where maternal clones are implanted into dairy cows and all beef cow replacements are sourced from the dairy industry. Of course, there need not be any genetic relationship between the implanted embryo and the recipient dairy cow. In addition, terminal male clones could similarly be sourced from recipient dairy cows for use in natural mating in beef breeding herds. The use of male clones for natural mating thus provides beef breeding cow herd owners with access to elite genetics for growth and carcass traits on a scale previously only available through the use of AI.

The vision of cloned elite breeding cows naturally mated to cloned terminal sires, all sourced from embryos transferred into dairy cows, would further consolidate the relationship that cur-

TABLE 3: Number of recipients, percentage recipients calving, percentage calving singles and twins, and number of calves born.

Source	Total No. Recipients	% Recipients Calving	% Recipients with Single Births	% Recipients with Twin Births	No. Calves Born per 100 Cows
		0	1	2	
Cummins *et al.*, 1993	481	65	29	36	101
Cummins *et al.*, 1993	541	63	30	33	96
McMillan *et al.*, 1993	128	43	22	21	64
Guerra-Martinez *et al.*, 1990	325	64	25	39	103
Izaike *et al.*, 1990	60	50	27	23	73
Sreenan & Diskin, 1989	89	62	34	28	90
Sreenan & Diskin, 1989	76	64	34	30	94
Anderson *et al.*, 1978	48	64	21	33	87
All Studies	1748	62	28	34	96

rently exists between the beef and dairy industries in New Zealand. Such a vision would highlight the grafting together of reproductive and genetic technologies and the cattle industries. A major missing link is the bovine gene map. This map, together with embryonic markers for productive traits, would significantly assist with the identification of elite material for cloning.

SUMMARY AND CONCLUSIONS

Using a broad definition for reproductive technology, it is clear that a raft of technologies are available for application in the beef breeding cow herd. The technologies can be simple with low cost and low risk. Such technologies tend to be management rather than physiological technologies. At the other extreme, further research is required to develop embryo-related technologies. Such technologies are currently costly and carry a relatively high risk of failure. However, they have the potential to deliver large returns. It is clear that the simple management-related technologies must form the base on which further higher technologies are grafted. Ultimately, the combination of higher reproductive technologies based on embryos, and genetic technologies based on the identification of elite genetic material at the embryo stage, will combine to significantly enhance performance from the beef breeding herd in New Zealand.

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