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'Clean, green and ethical' animal reproduction: extension to sheep and dairy systems in New Zealand

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ABSTRACT

In this paper, we present our approach for 'clean, green and ethical' (CGE) management in small ruminants and dairy cattle, in a context that is relevant to New Zealand livestock industries. We will focus in particular on reproduction and nutrition aspects, with several possibilities for CGE management: 1) control of the timing of reproductive events by using socio-sexual signals (the 'male effect') to induce synchronised ovulation in females; 2) 'focus feeding' - short periods of nutritional supplementation that are precisely timed and specifically designed for each event in the reproductive process; 3) 'nutritional pharmacology' – a term that reflects the possibility of using forages containing 'bioactive' compounds to improve rumen health and efficiency with environmental benefits through the reduction of methane emissions from ruminants; 4) maximizing offspring survival by a combination of management and nutrition; 5) genetic selection for fertility, fecundity and temperament. These tools involve novel ways of manipulating the endogenous control systems and production of animals. Ultimately, the CGE tools can be cost-effective, increase productivity and, at the same time, greatly improve the image of meat and milk industries in society and the marketplace.

Keywords: ruminant reproduction, rumen manipulation.

INTRODUCTION

Animal industries around the world are being challenged because of changing attitudes in consumers that are having an impact in the marketplace. We can recognise this trend through an increasing demand, in markets dominated by discretionary spending power, for products that are 'clean, green and ethical' (CGE) (Martin *et al*., 2004a). Interestingly, these issues have been widely recognised – hence projects such as the Food Animal Initiative at Oxford University (www.faifarms.co.uk), where CGE is reflected in the phrase 'Ethical, Environmental and Economic (3Es)'.

What does 'CGE' signify?

Clean: Minimising the use of drugs, chemicals and hormones; this demand is rarely supported by hard data, but it does highlight the major issue of food safety.

Green: Minimising the impact of the industry on the environment; this issue has a long history associated with animal waste in intensive industries and excessive use of fertilisers to generate forage. It is now very sharply focussed on the production of greenhouse gases by ruminants and, in Australia, maintaining plant biodiversity by expanding the feed base to include native and/or novel species in grazing systems.

Ethical: The obvious focus is animal welfare, an issue that can be a complex issue if the pursuit of a 'clean' image means, for example, avoiding antibiotics and thus compromising the welfare of the animals. In addition, ethical judgement needs to be applied to CGE practices in transport, manufacturing, processing, packaging and marketing, a topic that has recently had a very high profile in the international dairy industry.

In this paper, we will link this vision to two major animal industries in New Zealand, sheep meat and dairy cattle. In both cases, the productivity and profitability of the industries effectively depend on reproductive performance and nutritional efficiency.

The question is whether we can improve reproductive output without exogenous hormone regimens or high-level reproductive technologies? These technologies are effective and essential for the long-term future of the industries, but often have little direct, short-term benefit for the majority of producers (Martin, 1995; Martin *et al*., 2004a).

For producers, CGE management need not be difficult because, as we work towards a better understanding of the physiology and behaviour of our production animals, we should be able to improve productivity and profitability and, simultaneously, promote CGE practices.

CGE REPRODUCTION IN SHEEP

Our approach has been to concentrate on the natural control systems that the animals themselves use to cope with environmental challenges and ensure reproductive success (Martin, 1995). The most important environmental factors are photoperiod, socio-sexual stimuli, and nutrition. Reproductive responses to them are coordinated at brain level where all external and internal inputs ultimately converge into a common pathway that controls the secretion of gonadotrophin-releasing hormone (GnRH). This mix of inputs into the GnRH signal provides us with three major opportunities for management of reproductive efficiency. First, to control the timing of reproductive events, we can use socio-sexual signals, commonly called the 'male effect', to induce synchronised ovulation in females that would otherwise be anovulatory. Second, in 'focus feeding', we can use the responses to nutrition to design nutritional supplements that are aimed precisely and specifically at each individual event in the reproductive process. It is at these times, and more generally throughout the year, that we need to consider nutritional pharmacology and its role in developing CGE systems. The third opportunity is maximising the survival and development of the new-born through environmental management. In addition, we need to continue to draw on the power of genetics to improve fecundity and lamb survival through improved temperament. Genetic strategies are tightly integrated into the dairy industry but have only recently been gaining a foothold in the more traditional sheep industries where there has been a slower uptake of tools such as estimated breeding values of reproductive traits.

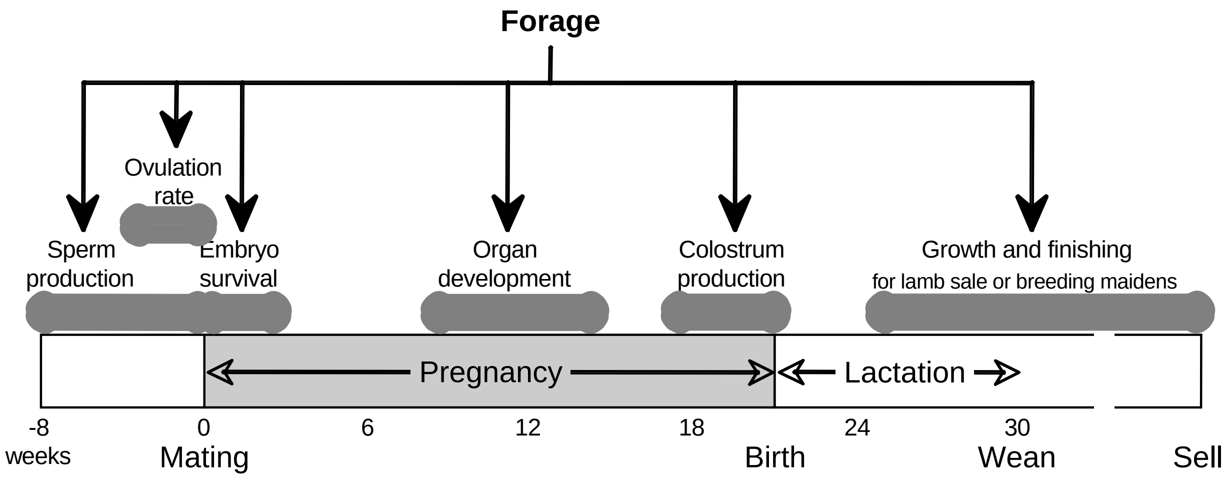
Control of the timing of reproductive events

Two aspects of timing cause problems for the industry by preventing the producers from deciding when their animals will conceive; seasonal breeding and postpartum anoestrus. In both situations, the lack of ovulation is due to lack of GnRH output. Exogenous hormones can be used very effectively to overcome the problem in most circumstances. However, with CGE as a goal, these practices need to be avoided and alternatives need to be found.

Changing the night-length: This could be attractive for small producers because it requires a relatively small investment, although there are limits for females because they would begin to cycle over a range of days or even weeks. However, with relatively large ewe flocks, most New Zealand farmers do not have the facilities to control night lengths. It is a far more attractive proposition for treating males so that their reproductive axis is working at maximum efficiency when they are used for the male effect (Delgadillo *et al*., 2002).

The male effect: The sudden introduction of novel males can induce ovulation in females that are reproductively quiescent because they are out of season or lactating (Martin *et al*., 1986; Rosa *et al*., 2002). Induced ovulations are sufficiently synchronised among a group of females to allow the use of strategies such as focus feeding, as discussed below, to improve litter size, foetal programming and neonatal survival. The male effect has the added advantage that it allows control over the season of births so that producers can take advantage of seasonal markets. In addition to interrupting seasonal anoestrus, it can shorten post-partum anoestrus in sheep, goats and cattle (Delgadillo *et al*., 2002; Geytenbeek *et al.,* 1984; Pérez-Hernández *et al*., 2002). The male effect is not perfect, even in

FIGURE 1: A 'Clean-Green-Ethical Package' for managing reproduction in sheep: periods of focus feeding are used to control the reproductive process, mostly to improve the reproductive success of the flock or herd. To accurately time the periods of feeding, mating must be controlled and brief, or ultrasound must be used to classify the mothers based on the age of their fetuses. Finally, the survival of the new-born must be maximised by a combination of good genetics and good management. Modified from Martin *et al*. (2004a).



the most favourable situations, and several areas need basic research (Martin *et al*., 2004b). To date, the use of the male effect in New Zealand has been minimal. This has been due to the lack of a consistent response in Romney-based breeds and the fact that it has generally only been effective just prior to the breeding season (Smith *et al*., 1989; Smith & Knight 1998).

Ultrasound: Skilled operators with modern instruments can provide two important types of information. First, the identification of single-bearing and multiple-bearing females so growers can use specific strategies to manage their different requirements during pregnancy and after parturition (Garrick, 1988). Second, accurate estimation of the age of a foetus (González de Bulnes *et al*., 1998) so we can use precisely timed nutritional supplements during pregnancy as discussed below.

'Focus feeding'

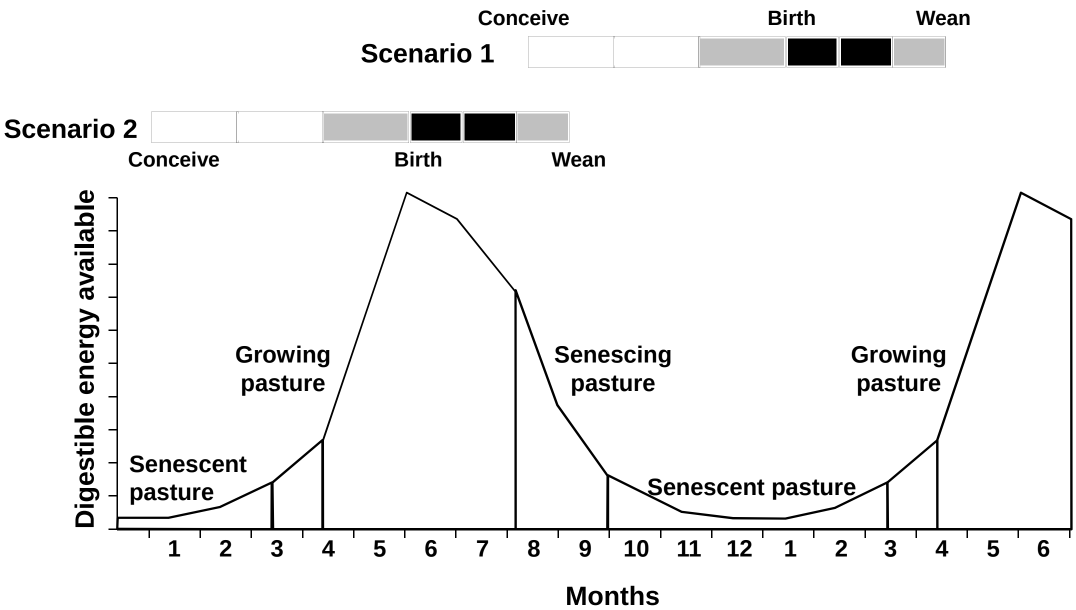
For all animal enterprises, feed is the primary limiting resource. There is thus constant economic pressure to reduce the amount used and then to ensure that, when used, it provides the greatest benefit. Strategic use of nutritional supplements such as grain supplements, or short periods of grazing quality pasture, has long been an important management tool in production systems that are precisely timed and specifically designed for each event in the reproductive process. Recent research suggests that we should focus on boosting sperm production before mating, maximising potential litter size by increasing the ovulation rate and maximizing postnatal survival and development (Fig. 1).

For each period of focus feeding, we need to consider both the composition and duration of the diet so they are cost-effective for the management system because the degrees of focus will vary among enterprises and among environments. At any or all of these times, we could use conserved or stored feed, or we could shift the entire reproductive process so that the critical periods are aligned with peaks and troughs in the availability of pasture (Fig. 2). For each of the periods indicated in Figure 1, the most cost-effective measure is to use forage and pasture, rather than grain supplements. We know, for example, that high quality pastures can be used to stimulate ovulation rate (Viñoles *et al*., 2009).

'Nutritional pharmacology'

This concept recognises the value of plants as 'bioactive' components of feed in addition to sources of energy and protein. Interest in this area has been rejuvenated and gained the attention of animal scientists, in both developed and developing countries, because of society-led demands that the livestock industries reduce their environmental footprint and discontinue the use of growth-promoting antibiotics. The rumen and its microbial community are a key focus of this attention because rumen fermentation is associated with many inefficiencies and production losses, such as methane production and microbial digestion of valuable dietary protein. Moreover, some gut microbes are associated with enteric diseases and

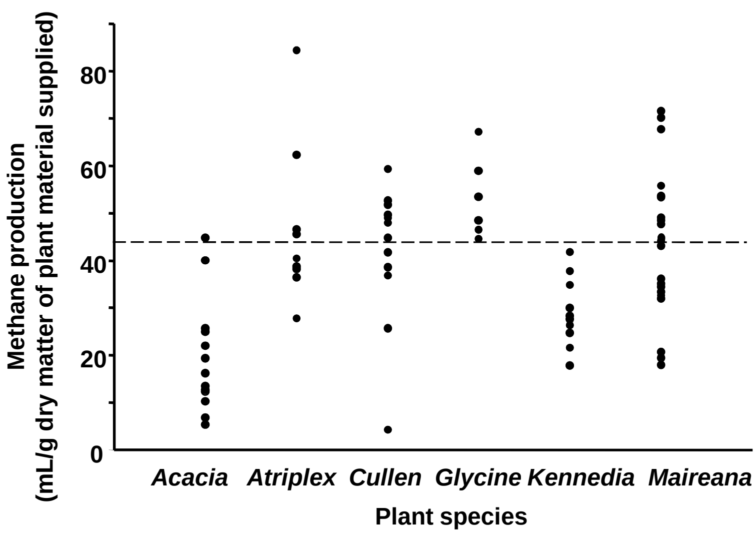
FIGURE 2: The annual cycle of pasture availability and its relationship with two potential reproductive scenaros. Scenario 1 reflects the relationship for a temperate genotype trying to breed in a 'mediterranean' region; Scenario 2 is typical of animals adapted to temperate regions, with major reproductive events typical of a strict 'short-day breeder'. Modified from Martin *et al.* (2008).



rumen disorders such as lactic acidosis and bloat. Antibiotics have been used widely in farm animals because they can control the microbes responsible for these inefficiencies, diseases and disorders, and they act as growth promoters. This practice has already been banned in Europe because of the belief by consumers that animals that are regularly fed antimicrobial growth promoters become reservoirs of resistant bacterial strains that may be transferred to humans. There is now a sense of urgency within the scientific community to find safer alternatives to antibiotics and 'natural' ways to improve rumen function and gut health.

A variety of fodder plants contain secondary compounds with 'bioactive' properties in the gut (Heckendorn *et al.,* 2007; Newbold, 2007; Soliva *et al.*, 2008). These plants have the potential to contribute to the nutritional supply of the animal whilst also offering natural replacements to antimicrobial growth promoters and anthelmintics in livestock production. For example, feeding tannin- or saponin-containing plants can decrease ruminal protein degradation and improve the efficiency of nitrogen utilisation, reduce ruminal gas formation and prevent bloat, influence methane production, and affect gastrointestinal nematodes (Carulla *et al.*, 2005; Iqbal *et al.,* 2002; Waghorn, 2003; Wallace *et al.,* 1994; Woodward *et al.,* 2004). The nutritional pharmacological inputs therefore provide ideal opportunity to reduce the use of antimicrobial growth promotants ('clean') and decrease methane production from ruminants ('green'), as well as manage ruminal disorders and internal parasites ('ethical').

FIGURE 3: Examples of distribution of plant samples investigated in the 'Enrich' project according to the methane produced by rumen microbes *in vitro* when incubated with different plants. Dotted line represents oaten chaff as a positive control. (Z. Durmic, Unpublished data).



We have investigated Australian native plants, mainly perennial shrubs, for their potential to be incorporated into multi-purpose 'healthy' grazing systems (Revell *et al.*, 2008). The value of the plants has been assessed on their bioactivity and potential to improve rumen function and gut health, as well as their nutritional value and biomass. We have screened over 100 native plants in an *in vitro* batch culture system using rumen fluid from sheep.

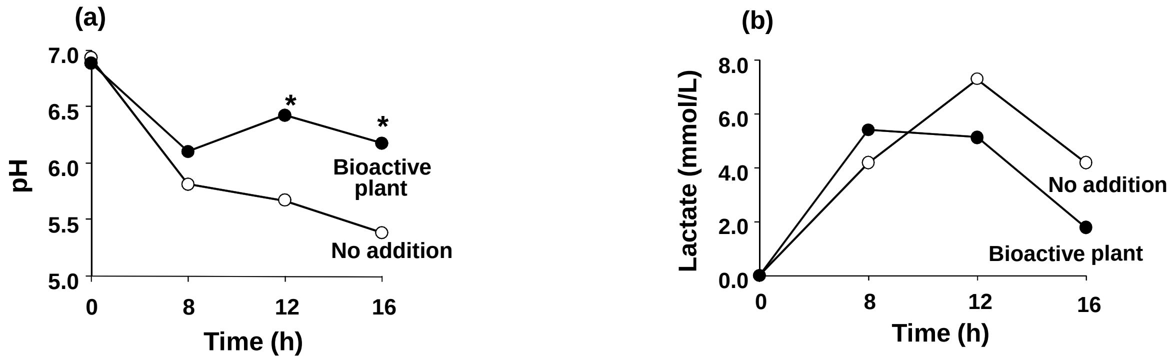
In comparison to an oaten chaff control, we have found that over half have good fermentability characteristics in terms of gas and VFA production. A range of plant species were capable of producing less methane than the control, but there was great variability observed within same plant genus. Some examples of this are shown in Figure 3. A wide spectrum of plants were also capable of inhibiting helminths (Kotze *et al.,* 2008) and the bacteria responsible for ruminal biohydrogenation (Durmic *et al.*, 2008b) or lactic acidosis (Hutton *et al.*, 2009).

Durmic *et al.* (2008a) have also confirmed some of these findings *in vivo* in sheep that were dosed with grain to induce acidosis, where a single dose of 'bioactive' plant maintained rumen pH above 6.0 and prevented significant accumulation of lactate (Figure 4).

It is not surprising that nutritional pharmacology has also generated interest in New Zealand, particularly for reducing methane emissions, because methane production from ruminants has been estimated to account for 35% of all greenhouse gases (Woodward *et al*., 2004). Studies on legumes with high nutritive value that also contain condensed tannins, such as birdsfoot trefoil (*Lotus corniculatus*) and sulla (*Hedysarum coronarium*), have demonstrated a significant reduction in methane production per unit of dry matter intake in cattle when compared to perennial ryegrass (Woodward *et al*., 2002; Woodward *et al.,* 2004), with the condensed tannins accounting for 66% of the difference between the lotus and ryegrass.

Despite the amount of information available about the bioactivity of secondary compounds in some plants and their potential to improve rumen function and gut health, we are yet to develop systems where these plants are integrated into a CGE livestock production system that is profitable and sustainable.

FIGURE 4: (a) pH and (b) lactate concentration (mmol/L) in sheep dosed with grain to induce acidosis, without additive (No addition) and combined with 'bioactive' plant (Bioactive plant). Modified from Durmic *et al.* (2008a).



Maximising the survival and development of the offspring

Ensuring the survival of the offspring ensures a return on all investments in other aspects of the reproductive process, particularly genetic gain, because the newborn by definition, carry the best genes. In addition, there is little doubt that, in the future, it will be seen as unethical to promote high birth rates if management systems are inadequate to ensure that the new-born survive and prosper. There are four avenues of improvement: a) feed supplements that will improve colostrum production (Banchero *et al.*, 2006); b) feeding levels and herbage types in mid- to late-pregnancy to increase multiple born lamb birth weights and ewe and lamb behaviour (Morris & Kenyon 2004; Everitt-Hincks *et al.*, 2005; Corner *et al.*, 2008; Kenyon *et al.*, unpublished); c) genetic improvement of ewe temperament as discussed below and d) management of flocks during birth so that the formation of the mother-young bond is promoted and not disrupted (Nowak, 1996).

Genetic solutions

There has been a lot industry interest in genetic selection for calm temperament for two reasons. Firstly, it has a high heritability for a behavioural character of about 0.4 in Merinos; (D. Blache and D. Ferguson, Personal communication, 2009) and secondly, there is a significant benefit for lamb survival, particularly for multiple births (Murphy *et al.*, 1994). There is also scope for selection of lamb survival as a trait itself, specific genes and mothering ability, as means of improving lamb survival (Slee *et al.* 1991; Lopez-Villalobos & Garrick 1999; Everitt-Hincks *et al.*, 2005; Forrest *et al.*, 2006; Sawalha *et al.*, 2007).

Ovulation rate can be improved with focus feeding, but this only allows the animals to express its genetic potential. Therefore, for the best overall outcome, selection for genetic improvement is necessary. However it could be argued, that some New Zealand farmers have had difficulty coping with the lambing percentages that they have already achieved. Therefore no further increases in ovulation rates are warranted under these conditions. Instead better management systems need to be developed using the principals of CGE to improve lamb survival and growth.

AVOIDING 'DOWN TIME' FOR RUMINANTS

In all ruminant-based industries, there needs to be a drive to advance the first conception. There are three reasons for this:

i. Increased rate of genetic gain: Young animals, by definition, represent the best genetics so delaying their first pregnancy decreases the rate of genetic gain because it extends the generation interval;
ii) Time to rebuild a flock: Any widespread policy of delaying first conception limits the rate at which a flock can be rebuilt after a decline in numbers, such as that we have seen in wool sheep over the past 15 years;
iii) Production per unit of methane: Females that are not breeding are still producing methane, increasing the amount of greenhouse gases per unit of production of carcass or milk. This issue magnifies the consequences of postpartum anoestrus in dairy cattle and offspring mortality in the sheep industry.

In the sheep meat industry, this issue applies to most 'maidens' in Australia and to most 'hoggets' in New Zealand. It requires research, development and adoption to overcome farmer scepticism (Kenyon *et al.*, 2004a) on factors that delay puberty and the low fertility of young ewes. Less than a third of ewe hoggets are currently presented for breeding in New Zealand. Current reproductive rates of hoggets in New Zealand are varied and poor with an average lambing percentage of approximately 60% (Kenyon *et al.*, 2004b). The male effect, through the use of vasectomised rams has been shown to increase the proportion of hoggets successfully bred, especially early in the breeding period (Kenyon *et al*., 2005; Kenyon *et al*., 2006). This is an area that warrants further investigation to identify systems that ensure a consistent response and to determine how 'early' in the breeding season mating be brought forward. Earlier breeding may allow more time for the young dam to achieve a suitable live weight at her second breeding. This is a major concern of farmers (Kenyon *et al*., 2004a). Recent data suggests that a short term increase in nutrition pre-breeding under pastoral conditions can improve hogget reproductive performance (F. J. Mulvaney, Unpublished data). It is therefore possible that a combination of 'focus feeding' and the male effect may be the means forward to substantially improve reproductive performance in hoggets. There is also scope for the use of alternative herbages from both a nutritional and a 'bioactive' perspective, as a possible means of improving ewe hogget performance. Ewe hoggets have traditionally suffered a period of 'ill-thrift' during autumn. Two major contributing factors to this have been poor herbage quality and internal parasitism. Grazing ewe hoggets on *Lotus corniculatus* has improved liveweight gains although it did not affect reproductive performance (Proctor *et al*., 2006).

THE DAIRY COW PROBLEM

Reproductive performance in modern dairy herds has declined remarkably over the past 15 to 20 years. The problem appears to be caused, at least partly, by changes in the metabolic processes that underpin genetic progress toward improved potential for milk output (Chagas *et al.,* 2007). Arguably, the intensive, single-trait selection, has led to the development and spread of a genetic disease for which the major symptom is low infertility. The precise nature of the problem is not entirely clear, but seems to involve a breakdown in the homeostatic link between GH and IGF-I. This problem has been, to a large degree, covered up by the development of pharmacological systems for inducing ovulation and fertility, and by highly optimised nutritional management using 'total mixed rations' (TMR). This combination of management tools has prevented its early manifestation and thus industry acceptance, of dysfunctional links between metabolism and reproduction.

It would appear that, in current Holstein herds in North America, cows receive an average of 12 to 15 hormone injections before they conceive postpartum (K.L. Macmillan, Personal communication). Moreover, due to the continued production of methane during 'down time', there is an ecological issue. These two problems do fit the goals of CGE management.

Genetic solutions

The apparent conflict between milk production and fertility is not inevitable because traits for fertility can be included successfully in selection indices, as has been demonstrated in Scandinavia (Philipsson & Lindé, 2003). There is also a relatively strong emphasis on fertility traits in the national selection indices of the 15 countries who are members of International Bull Evaluation Service (INTERBULL). In addition, reproductive performance is not always associated with milk production (Snijders *et al*., 2001).

However, the heritability of most fertility traits such as calving interval, days open and pregnancy rates, are quite low at less than 0.05, due to large contributions by non-genetic factors, such as differences among cows, AI technician and management protocols. This has led to the development of a completely new selection system based on the prediction of the breeding value of sires with a model that includes 'survival analysis' of the intervals from parturition to conception in daughters (Schneider *et al*., 2005). Because almost all dairy cattle are bred by artificial insemination, it is feasible to collect survival data for this model. Another strategy is to use traits with a higher heritability, more readily available records, and good genetic correlations with fertility to reduce the risk of reproductive difficulties in cows (Banos *et al*., 2004; Pryce *et al*., 2000; Roche *et al*., 2004).

Nutritional manipulation

With respect to the nutritional inputs built into the CGE framework, there is little room to move in a TMR system because the feeding regime is precisely and maximally controlled. However, in the pasture-based systems typical of the New Zealand dairy industry, options may be available for nutritional pharmacology. Even if reproductive function is resistant to acute manipulation by focus feeding, there will be scope for the introduction of forages that help control parasites and reduce methane emissions.

The male effect in cattle

There is a sizeable body of literature describing a male effect in cattle. Although most of the work has been done on beef cattle, including zebus, but there are several reports of advanced ovulation in postpartum dairy and double-purpose cows (Ungerfeld, 2007). Overall, the effect is not as robust, with respect to endocrine responses or ovulation, as it is in small ruminants, and some reports are dismissive of the possibilities. However, there seems to be room for further exploration and future research and development may find ways to refine and use this approach to induce ovulation and thus control the timing.

CONCLUSIONS

Understanding the reproductive responses of animals to exteroceptive factors, such as photoperiod, nutrition, socio-sexual signals and stressors, can help us develop 'natural systems' as replacements for exogenous hormones and drugs for controlling and improving the productivity of farmed ruminants. In addition, we can easily genetically improve our animals through a calm temperament, to greatly improve many aspects of their productivity. Finally, we need a serious research effort in the area of novel forages that can be used to improve health and also cut down greenhouse gas emissions. The use of such 'clean, green and ethical' tools in the management of our animals can be cost-effective and improve profits. At the same time it can greatly improve the image of our industries in society and the marketplace. Finally, it is possible to include plants that provide nutrients and beneficial secondary compounds for grazing livestock, which are profitable and sustainable in mixed enterprise farms.

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