Increased lambing frequency: the opportunity to simultaneously increase the profitability and sustainability of sheep meat production in southern Australia

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1 Introduction

Increasing the lambing frequency or accelerated lambing is not a new concept and the potential for some breeds to lamb more frequently than once annually had been documented as early as the 1930's. During the late 1960's and 1970's several authors indicated that various breeds could achieve regular lambing intervals of 6-8 months, and concluded that there was a need to further investigate the effects and interactions between nutrition, lambing time and lactation (Hulet & Foote 1967; Hunter 1968). Since then accelerated lambing systems have been researched widely and in different environments, including the United Kingdom (Robinson & Orskov 1975), United States of America (Jenkins & Ford 1991), Canada (Fahmy & Lavallee 1990), Spain (Vallis Ortiz 1983), Germany (Mendel *et al* 1989), Morocco (Lahlou-Kassi 1989) Egypt (Aboul-Naga 1989) New Zealand (Morris *et al* 2004) and Australia (Fogarty *et al* 1992).

Despite the international interest in these systems, little implementation of any form of accelerated lambing has occurred at commercial scale in southern Australia. Limited adoption has most likely occurred due to the physiological constraints associated with breeding sheep at shorter intervals and the inability of forage and grazing system to provide the required pattern of feed supply. In addition the majority of research that has occurred internationally is based on intensive, small landholder systems that often comprise a housed component, and there is limited information on the economic performance and profit benchmarks at the per hectare and enterprise level.

In southern Australia it is well recognised that enterprise profitability of grazing systems is inherently linked with the level of resource utilisation, namely pasture production and utilisation, with the latter primarily determined by the stocking rate per unit of area. The importance of stocking rate to enterprise profitability is due to the direct relationship with the amount of meat and wool produced, and hence the level of income achieved. However, its relationship to enterprise profitability is unclear when the production of meat products is maintained or improved at potentially lower stocking rates when the lambing frequency is increased.

A reduction in stocking rate may enable a more flexible approach to implementing both new and existing forage species that require alternative management to those species under a purely stocking rate driven enterprise. The implementation of these species could provide a range of options for the management of ongoing and new environmental challenges, but also provide the opportunity to improve the pattern and value of feed supply and maximise livestock productivity. The challenge of this review is to investigate the potential of accelerated lambing for southern Australian and determine the potential to achieve simultaneous benefits to both animal and forage system through the application of accelerated lambing.

2 Accelerated lambing systems

'Accelerating' the lambing system is undertaken by decreasing the period from one parturition to the next, also referred to as the inter-lambing interval. The three most notable accelerated lambing systems are lambing 3 times in 2 years (3/2) (Geisler *et al* 1977; Fogarty *et al* 1992; Schoeman *et al* 1995; Speedy & FitzSimons 1977), lambing 5 times in 3 years (5/3) (Hogue 1986; Lewis *et al* 1996; Morris *et al* 2004) and lambing twice in 12 months (2/1) (Land & McClelland 1971; Whiteman et al 1972; Walton & Robertson 1974; Jenkins & Ford 1991). Respectively, the inter-lambing interval for these systems is 8, 7.2 and 6 months, which potentially equates to 1.5, 1.67 and 2.0 lambings per ewe per annum.

2.1 Biological efficiency and total output

Several studies have identified that the biological efficiency of accelerated lambing systems is higher than systems with a single annual reproductive cycle (Large 1970; Schoeman et al 1995). The purpose of decreasing the inter-lambing interval is to capitalise on the large proportion of energy dedicated to the maintenance of the ewe, which can as high as 75% (Coop 1962; Dickerson 1978), and improve the efficiency of total energy use.

The biological efficiency of meat production is defined by Large (1970) as being the weight of carcass produced per 100 units of digestible organic matter (Figure 1). The biological efficiency is an important measure for between comparisons of different animal production systems and encompasses all the factors that contribute to the output for a given level of input. For example, in sheep meat producing systems the output will be governed by the initial conception rate, the level of fecundity, the rate of lamb survival and the grow rate of those lambs to slaughter. It must be noted that the definition presented here does not account for wool production.

$$\text{Biological efficiency} = \frac{\text{Carcass weight (kg) x 100}}{\text{Digestible organic matter}}$$

Figure 1. The biological efficiency of meat production (sourced from Large 1970).

When the biological efficiency is compared (table 1), a diminishing return for each increment of litter size and lambing frequency is observed, although actual lamb output increases in a linear manner. It is critical to note that the highest incremental change in efficiency is the movement in litter size from a single bearing ewe to a twin-bearing ewe in all lambing frequencies (+46-64%), and that doubling the lambing frequency in a single bearing ewe is equal to a twin bearing ewe in an annual lambing system. The proportion of multiple bearing ewes is therefore an integral component of maximising the biological efficiency of any system, but could be considered less important for maximising per head output when lambing frequency is increased.

Table 1. The increase in lamb numbers by increasing litter size and lambing frequency, and associated biological efficiencies (Large 1970).

Lambing frequency	1.0	1.5	2.0	1.0	1.5	2.0
Litter size	Lamb number (n/year)			Biological efficiency		
1	1.0	1.5	2.0	3.9	5.3	6.5
2	2.0	3.0	4.0	6.4	8.2	9.5
3	3.0	4.5	6.0	8.2	10.0	11.2
4	4.0	6.0	8.0	9.5	11.3	12.5
5	5.0	7.5	10.0	10.5	12.3	13.3

The greatest efficiency is achieved from lambing twice per annum with a litter size of 5 lambs, however, in the context of Australian production systems litter sizes greater than 2 lambs rarely provide any productivity increase due to higher lamb mortality. An increase in lambing frequency to 1.5 and 2.0 lambings per annum will increase the biological efficiency by 28 and 48% respectively in twin bearing ewes and by 35 and 67% in single bearing ewes.

2.2 Mating structure

When the lambing frequency is 'accelerated' it is often in conjunction with a mating structure that allows re-mating of ewes that failed to conceive in the initial mating or to provide greater continuity of lamb supply. The rapid re-mating of ewes is important to overall biological efficiency as it will reduce the time to re-conception if ewes fail to conceive on their designated mating and it can increase the selection pressure and removal of non-pregnant females after successive failures. A range of systems with different lambing intervals and mating structures, and the subsequent opportunities for re-breeding are detailed in table 1.

Table 2. Accelerated lambing systems and the implications for lambing interval and lambing frequency when re-breeding is undertaken at the first, second and third opportunities when ewes are identified as non pregnant and moved into the next flock to be re-bred (sourced from Hogue 1987).

				Lambing interval (months)			Lambing frequency (per year)		
Lambing opportunities per year	System	Intended lambing frequency	Number of flocks	1st mating	2nd mating	3rd mating	1st mating	2nd mating	3rd mating
1	Annual	1/1	1	12.0	24.0	36.0	1.00	0.50	0.33
2	2/1	2/1	1	6.0	12.0	18.0	2.00	1.00	0.67
3	3/2	3/2	2	8.0	12.0	16.0	1.50	1.00	0.75
4	Morlam	4/3	4	9.0	12.0	15.0	1.33	1.00	0.80
5	STAR	5/3	3	7.2	9.6	12.0	1.67	1.25	1.00
6	CAMAL	3/2	4	6.0	8.0	10.0	2.00	1.50	1.20

In general, the more flocks that can be managed out of phase, the greater opportunity there is to transfer ewes to another flock for rebreeding and restrict the inter-lambing interval as short as possible. For example, the 3/2 system with two flocks has the opportunity to breed at 8, 12 and 16 month intervals after three mating attempts, whereas the CAMAL system, which employs the same 3/2 lambing frequency but with four sub flocks, can achieve four successive mating attempts within a 12 month period. Although systems with more sub flocks increase the ability to apply selection pressure, the complexity of flock management is increased. It is likely for these reasons that the two most common applications of mating structures are the split flock for the 3/2 and the STAR system (Hogue 1986) for the 5/3 lambing frequencies.

In the 3/2 system the flock is commonly split into two sub flocks that are run approximately 4 months out of phase with each other. Ewes that did not conceive in the first flock are moved into the second (Figure 1). This method has been employed in simulation models (Geisler et al 1977) and in practice (Rawlings et al 1987; Tempest 1983) with success in overcoming constraints to conception and improving the consistency of lamb supply. Fogarty et al (1992) speculated that overall lamb production in their study could be increased by implementing a split flock to allow re-mating of non-pregnant ewes.

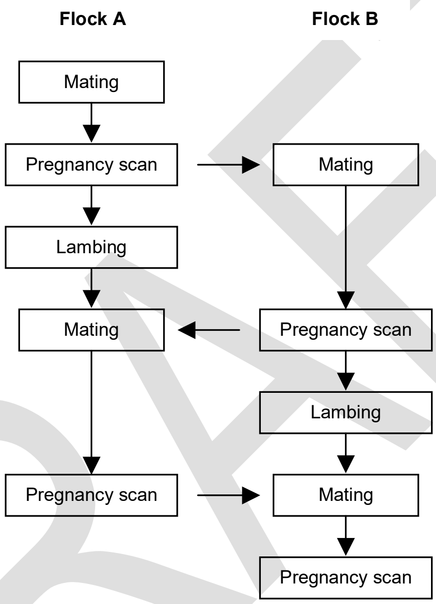

Figure 2. Diagram of the split flock structure of the 3/2 lambing frequency showing how rapid re-mating of ewes can occur by running two flocks out of phase.

A flock structure that incorporates a 5/3 lambing frequency is the STAR system. Three flocks are mated successively 73 days apart and create five lambing periods throughout the year (Figure 1). Morris et al (2004) concluded that low pregnancy rates in the non-breeding season limited the high performance of the STAR system. Lewis et al (1996) showed that the STAR system had lower conception during non-breeding seasons and the postpartum period was not a limiting factor to re-mating in the breeding season, but fertility in the non-breeding season was always higher in ewes that missed the previous mating and had additional time to recover.

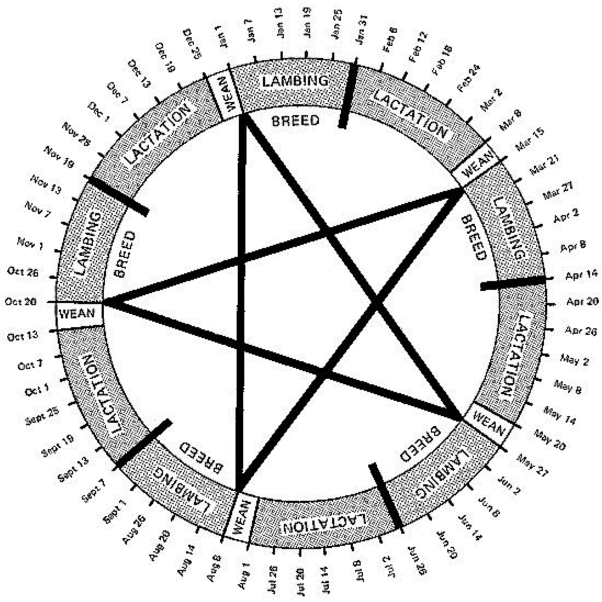

Figure 3. The STAR system showing the timing of events (each line between two star points represents the cycle from joining to weaning) (Sourced from Hogue 1987).

There is no direct comparison of these lambing frequencies and mating structures present in the literature. However, Fahmy and Lavellee (1990) compared a 3/2 and 5/2 lambing frequencies without the associated mating structures. The 5/3 system had lower production as a result of lower conception rates and achieved an annual lambing rate of 1.51, lower than the expected 1.67. The 3/2 system achieved 1.5 lambings per year. Fertility (ewes conceived per number of ewes exposed) for the 3/2 systems was 98% compared to 79% for the 5/3 system. It is not clear why the conception rate was lower in the 5/3 system and could be a result of a higher proportion of mating periods over the three year period occurring in the non-breeding season and additively may have been accentuated by the lambing status and shorter duration from the previous lambing (Lewis et al 1996).

A concurrent outcome of these mating structures is the increased number of lamb crops per year and reduced seasonality of lamb supply. As describe earlier, when flock structures are incorporated the complexity of management and number of annual events increases. If we consider a single flock for both a 3/2 and 5/3 frequencies, the relative complexity is low as there would be only a maximum of 2 lambings per year. The STAR system has a high level of complexity with five lambing periods per year. Similarly, if a 3/2 system is split into two sub flocks then the number of lambing periods will increase to a maximum of four per year.

If we consider the deficit periods in Australian production systems (Autumn-Winter) and the time to reach slaughter specifications, it is questionable whether more than two lambs crops per year is of any greater benefit. In addition the design of forage systems to cater for more lamb crops per year would create a high level of complexity. It appears that the level of management input will be driven by the variation across a flock in the repeatability of conception rate at each designated mating. If reproductive success is high, the requirement to implement mating structures to increase re-mating opportunities will be reduced. The value of improving the consistency of supply by implementing these flock structures remains unclear and there are likely to be tradeoffs between management input and the level of reproductive potential to rebreed. This requires further investigation with emphasis on the level of response in marginal value for increments in success at re-breeding.

2.3 Results from accelerated lambing studies

The repeatability of the ewe to conceive and produce either a single or twin lamb at each lambing is highly important. Individual ewes can achieve two lambings per year, but this is rarely sustained at a flock level (Robinson & Orskov 1975). Numerous studies have indicated similar sentiment, with reasonable, but not complete success. Other studies however have recorded on a flock or group basis an annual lambing frequency below the intended rate due to reduced conception rate (Jenkins and Ford 1991; Sormunen-Cristian & Suvela 1993).

At six-month lambing intervals, Land and McClelland (1971), in adult ewes over two years of age achieved on average 5.8 lambs from three lambings. Similarly, Walton and Robertson (1974) over 5 consecutive matings achieved a conception rate of 84.9%, and returned an equivalent of 3.54 lambs per ewe for a 12 month period, although this was undertaken with early weaning of lambs at 24-48 hours after birth. Whiteman *et al* (1972) had 36% of lambs conceived during a season that the ewe had lambed, and 72% of autumn born lambs were from ewes that lambed the previous spring. However, Duncan and Black (1978) had only one ewe conceive at each mating over two years and conceded that it may not be any more profitable than a well managed flock lambing once a year and further investigation was required.

For eight-month lambing intervals, Fahmy and Lavallee (1990) weaned 2.53 and 1.61 lambs per ewe per year for Polypay and Dorset ewes respectively. Notter and Copenhaver (1980), over 5 years with various crosses of Finnish Landrace, Rambouillet and Suffolk, produced an average lambing rate of 2.69 lambs per ewe per annum. Rawlings et al (1987) produced 2.54, 1.98 and 2.83 lambs per ewe per annum for crossbred, purebred and Finn Columbia crossbred ewes respectively, and the intensified management increased annual lamb production by 37% over once a year lambing. Dzakuma *et al* (1982) across five breed combinations of Finnsheep, Dorset and Rambouillet had an overall production of 1.92 lambs per ewe per annum. Fogarty *et al* (1992), across three crossbred ewe genotypes, over three mating periods (February, October and June) had on average 1.37 lambs born per ewe joined with the lowest occurring for the October and June joining (1.30 and 1.29 respectively) and 1.52 for the February mating.

In the 5/3 lambing frequency, which has tested mainly in the context of the STAR system, Lewis *et al* (1996) had 55 and 21% fertility for ewes lambing during favourable and unfavourable mating periods and produced 1.54 and 1.44 lambs per ewe during the same periods. Lamb survival was 81 and 82% for those lambings that occurred from favourable and unfavourable mating periods. The average age of lambs at weaning was approximately 54 days at 15-16 kilograms live weight. Preliminary results from Morris *et al* (2004) with the STAR system, achieved 75 and 65% pregnancy rates and 1.42 and

1.22 lambs weaned for East Friesian and Romney ewes respectively. For the 5/3 lambing frequency without the STAR mating structure Fahmy and Lavallee (1990) recorded an overall fertility rate of 79% and a annual lambing frequency of 1.54 and 1.57, and 1.79 and 1.60 lambs weaned per ewe for Polypay and Dorset ewes respectively.

2.4 Economics of accelerated lambing

It has been speculated that the profitability of accelerated lambing systems will not match those of current annual lambing systems given increased costs (Jenkins and Ford 1991; Suvela & Sormunen-Cristian 1993). In general, poor results in ewe reproduction, increased nutritional inputs and increased labour requirements appear to be limiting factors, however a significant cost of many of the systems undertaken experimentally have been the use of confinement for lambing and mating, and these systems do not provide a likely representation of Australian conditions. Additionally, there is little information available on financial and productivity benchmarks under commercial or extensive conditions in comparison with conventional systems.

However, studies dedicated solely to the economics and simulation of accelerated lambing systems have identified a positive outcome in favour of these systems (Morel *et al* 2004; Fisher 2001; Wang & Dickerson 1991). In particular, Fisher (2001), utilising linear programming, found that the contribution margin per ewe was up to 2.15 times more in the 3/2 system than an annual lambing system. Contribution margin is defined as the revenue generated, less the variable costs. The margin from the STAR lambing system was 16% lower than the 3/2 system, and this was due to the marketing of lambs during periods of low demand, however it is speculated that this system may spread financial risk due to a consistent cash flow associated with the marketing of regular lamb crops.

More recently, Morel *et al* (2004) found that at similar lambing percentages, the STAR system earned an extra 26% income over an annual system, and considering a 10% premium for out of season lamb production, the STAR system could potentially generate an extra 56% return in profit. In both studies of Morel *et al* (2004) and Fisher (2001), the accelerated lambing systems have benefited from exploitation of high demand, low supply markets. The longevity and consistency of market premiums is uncertain, particularly given the price taking nature of agricultural production, where the premium or demand for a product is often diminished by a reactive oversupply. Over the long term the likely economic benefit from accelerated lambing will be from a higher return from fixed inputs.

Wang and Dickerson (1991) simulated the life cycle efficiency of different lambing intervals and found that when reproductive rate was low, the benefits in cost reduction for decreased lambing interval were high. Inversely, when reproductive rate was high, the benefits from decreasing lambing interval were reduced. This scenario is in agreement with earlier discussion of biological efficiency, where the largest gain from increasing lambing frequency is achieved from single bearing ewes, which is greater than can be achieved from increasing lambing frequency in flocks that already have a high reproductive rate.

Although experimental data suggests that the economics of accelerated lambing may not be any better than well managed annual systems, several economic studies have highlighted the potential of these systems to be superior. However, there is a significant deficiency in any benchmarks or indicators of the possible success of these systems in forage based grazing systems in southern Australia. Given that economic prosperity is a major influence on adoption of technical or management changes in most agricultural enterprises, the development of relevant benchmarks should be a priority if it is proven that accelerated lambing is a feasible and successful economic alternative.

3 Ewe reproduction

The limits of sheep reproduction are simple, given a gestation length of approximately 147 days, a ewe should be able to reproduce more than once per year and could possibly achieve a maximum of two lambings in 12 months (Hunter 1968; Jenkins & Ford 1991; Hulet & Foote 1967). However, lambing more than once per annum is rarely practiced, and in comparison to other meat industries, the sheep industry significantly underperforms in reproductive output considering its potential capacity (Table 2). Historically, increasing reproductive efficiency was not an important selection, breeding or productivity driven objective. For example, in the pork industry a key performance indicator is the number of piglets produced per sow annually, because it directly relates output to the fixed cost of feed consumed by the sow. An economic constraint has therefore reinforced selection strategies towards reproductive efficiency, whereas the sheep industry, due most likely to its extensive nature, forage as a cheap nutrition source, its primary utilisation for wool production and the relative infancy and scale of meat production have not forced conscious, or even aided unconscious selection to improve reproductive performance.

Table 2. Current industry levels of reproductive performance of animals utilised for meat production in Australia with similar reproductive biology.

	Sheep	Pig	Cattle
Gestation length (d)	147 (144-152)	114 (109-120)	283 (277-300)
Oestrus cycle (d)	17 (16.5-17.5)	21 (18-24)	21
Litter size (n)	1-3	8-12	1
Parturition frequency (n/year)	1.0	1.8-2.4	1.0

Although traditionally the structure of the sheep industry has not placed emphasis on reproduction efficiency, the introduction of regimes to improve reproductive efficiency such as accelerated lambing would generally fail due to physiological constraints. The major constraints are the seasonal pattern of breeding and its interrelationship with nutrition and socio-sexual phenomenon of the ram effect, and the consistency of maintaining high fertility rates at shorter rebreeding intervals and its interaction with lactation and energy balance. Furthermore, genetic diversity amongst sheep breeds and selection policies will interact with these constraints and affect the success of these systems. Understanding the mechanisms that regulate these constraints will aid strategies to improve the reproductive efficiency of sheep.

3.1 Seasonality of sheep reproduction

The seasonality of sheep reproduction is an evolutionary mechanism to manage the extremes in annual climate variation and ensure parturition occurs in favourable conditions for survival of both mother and offspring (Fournier *et al* 1999; Rosa & Bryant 2003; Setchell 1992). Most sheep breeds originating from latitudes greater than 35° utilise decreasing photoperiod as a determinant for the onset of oestrous because it is a consistent variable between years that most closely represents the extremes in environment and the pattern of food supply. Alternatively, breeds originating from regions between the latitudes of 35° often have a longer breeding season that loosely follows photoperiod because these Mediterranean, subtropical and tropical regions have inconsistent or responsive feed supplies. Although photoperiod appears to synchronise reproductive activity with environmental phases, sheep have an endogenous rhythm that exists separately from photic stimulation (Rosa & Bryant 2003), and coordination of reproduction occurs at the brain level where all external and internal inputs converge for a common control of GnRH (Martin *et al* 2004).

Photoperiod does not fully account for seasonal breeding in all sheep and the mechanisms for oestrous induction can depend on the environment and management at the place of origin. These mechanisms are likely to have been developed by pressure from external forces, and studies on the domestication of livestock have identified how the movement away from a wild environment has led to morphological, physical and behavioural changes (Setchell 1992). For example Martin *et al* (2003) demonstrated that rams with a weak photoperiod dependency derived from a Mediterranean environment showed greater response to nutritional cues than rams originating from a temperate environment and strong photoperiod dependency. Further demonstration that nutrition can influence reproduction is the application of short term nutritional supplementation to increase ovulation rate (Martin *et al* 1986; Vinoles Gil 2003). The inconsistent nature of nutrient supply and the inability of photoperiod to mimic the supply in these environments have caused the breed to evolve with nutrition as an indicator or determinant for the onset of reproductive activity and the level of reproductive output.

In postpartum ewes inhibitory oestrogens present during pregnancy fall rapidly, and FSH secretion resumes within a few days and instigates a wave of follicle recruitment. However it appears that a combination of low progesterone and luteinising hormone (LH), do not support continued follicle maturation, ovulation and behavioural oestrous (Haresign et al 1983;). The ram effect can be used to override seasonal and lactational anoestrous in breeds that follow this weak photoperiod dependency, with the Merino as a prime example (Martin *et al* 1986; Oldham 1980; Pearce & Oldham 1984). Oldham (1980) showed that the ram effect could increase LH secretion and return the ewe to a normal oestrous cycle, however this oestrous cycle was often preceded by a silent ovulation that was absent of behavioural oestrous. The silent ovulation is characteristic of insufficient progesterone and appears to act as a precursor or priming mechanism to increase basal concentrations of progesterone and gonadotrophin's for latter ovulations.

These results demonstrate that not all sheep are controlled exclusively by photoperiod and some breeds have developed mechanisms dependent on factors more relevant to their environment. It could be possible to apply pressure, by selection or modifying environments, to design sheep that overcome seasonal breeding.

3.2 Rebreeding at short intervals

The potential capacity of sheep is large given the variation in litter size amongst different breeds (Land 1978; Haresign 1985; Fahmy 1996). Litter size is determined by the variation in ovulation rate and embryo survival, with a trend for more prolific sheep to have higher ovulation rate and higher embryo loss that results in greater net output compared to other less prolific sheep (Haresign 1985). Prolific sheep tend to have greater success of re-breeding at short intervals (less than 40 days) (Evans and Robinson 1977). In this study, the breed crosses with the largest mean litter size had the highest frequency of re-breeding (53%) compared to the lowest mean litter sizes (1.3 and 1.2) of 8.3 and 0% respectively.

The success of rebreeding is dependent on whether it occurs during the anoestrous or normal breeding season. When re-breeding is undertaken during the normal breeding season the number of ewes exhibiting oestrous is greater, and the time taken to resume the oestrus cycle is shorter. For example, Whiteman (1972) found that 71% of ewes lambing in the breeding season had an average interval to conception of 44 days, while 23% ewes lambing in the non-breeding season conceived at an average interval of 66 days.

The ability to rebreed at short intervals will also be determined by the stage of lactation. Ewes lactating with a single born lamb had greater success of re-breeding at shorter intervals than ewes rearing twin born lambs and these differences become larger as the interval and lactation length increase (Cognie et al 1975). Goulet and Castonguay (2002) reported that when the rebreeding interval increased from 75 to 90 days, ewe live weight and condition improved, along with lambing rate and the number of lambs born per ewe. Although they detected no significant differences at the 5% level and any trend for changes in reproductive performance were the result of significant differences between condition score at mating and live weight change between weaning and re-mating.

The differences between single and twin rearing ewes and live weight change between different intervals to rebreeding suggest that energy balance is a contributing factor determining the rate of re-breeding. Robinson et al (2006) concluded that for cattle, the degree of negative energy balance postpartum plays a significant role in determining the interval to first oestrous. It is likely this is not an endocrine response due to lactation per se, however an endocrine response driven by nutritional status because of the extra demand from lactation. Minimising the negative energy balance during late pregnancy and lactation will be a key area determining the ability to rebreed at short intervals.

3.3 Selection strategies

A major limitation for accelerated lambing systems is the ease that the new reproductive strategies can be changed in existing enterprises. Changing to accelerated lambing will require longer term selection, breed and management changes and the major challenge of implementing accelerated lambing systems is the catch-22 scenario, where to reach the point of having sheep that reproduce more frequently, the active selection for sheep to reproduce more frequently must be undertaken.

Selection for reproductive traits is often associated with low heritability and therefore is seen as a slow process with little gain.

The immediate opportunity in accelerated lambing systems is for selection strategies to be developed to overcome the effects of seasonal breeding, but also the consistency that sheep can re-breed at shorter intervals. Notter (1981) demonstrated that the repeatability for conception rate during the non breeding season, but not the normal breeding season, could be used for culling and improving the performance of remaining ewes in other seasons. However, the direct selection for litter size within any season would maximise performance of remaining ewes. In the STAR system it was shown by Lewis et al (1996) that continual selection of ewes breeding during the anoestrus period resulted in higher year round productivity. However, Fogarty et al (1992) found that there would be little benefit in selecting for breeding during the anoestrous period, but this was influenced by relative high success and limited variation in the traits measured.

The management of re-breeding success at the farm level is now easily managed with pregnancy scanning services that in the past may have been cost restrictive or simply not available. Strategies that allow selection pressure to be applied in annual lambing systems that can make the transition to accelerated lambing simpler are required. For example in the first instance the possibility of splitting flocks and mating one flock during the anoestrous period, or allowing rams access for limited periods during the early lactation period may be opportunities for applying selection pressure in current annual systems without fully committing to accelerated lambing. However, these strategies are required to be investigated further for their feasibility to actually improve reproductive success.

4 Forage and grazing systems to facilitate accelerated lambing

For accelerated lambing systems to be successful, the forage system must be able to provide a uniform nutrient supply and minimise the requirement for external supplements to achieve improvements in profitability. However, most forage systems are based upon only a few species and do not provide the maximum productivity at all spatial and temporal levels. Current grazing systems philosophy is based on uniform application of management, inputs and species distribution across farm landscapes that are diverse in soil resources, geography and species suitability.

Most farming systems in the high rainfall zone of southern Australia would not support increased lambing frequency without significant supplementation due to inconsistent pasture supply and quality during late spring, summer and autumn. Significant effort has been undertaken in pasture productivity, forage production and species development, but until recently most grazing systems were based on a small number of grass species that had a limited range of cultivars, and small proportions of legumes (Reed 1996; Quigley 1991). Renewed attention is now focused towards summer active perennial species to reduce groundwater recharge and provide salinity control, however the benefits from these species is likely to extend to other environmental problems of groundcover, erosion and nutrient loss. The majority of these species are not new, and have been researched extensively but with little uptake at the farm level.

4.1 Current grazing systems

Southern Australia is broadly characterised as a Mediterranean environment that is subject to a forage deficits during the hot summer and cold winter months. Forage quality is low during the senescent and dormant periods from late spring to opening rainfall in the autumn. The majority of unimproved pastures consist of degraded native pastures with high proportion of annual grasses that generally have low soil fertility. In southwest Victoria only five percent of forage systems are considered improved, and of those improved forage systems, 90% contain perennial ryegrass as the primary grass component (Quigley 1992). Perennial ryegrass is commonly sown with subterranean clover to provide a winter and spring dominant feed supply, and is a popular mixture due to ease of establishment, the level of production, responsiveness to inputs and relative persistence in comparison to other species (Waller and Sale 2001; Reed 1987).

A large proportion of these improved forage systems experience continuous grazing, and pasture decline and persistence is a major limitation to maintaining productive species in these environments (Kemp & Dowling 1991). Persistence is compromised when continuous defoliation reduces storage capacity and subsequent translocation of labile carbohydrates from roots and stem bases that is required in the initial regrowth period before energy production can be undertaken by photosynthesis (Davidson 1978). Producers ranked persistence of pasture species only second to weed control and attributed dry seasonal conditions as the highest contributing factor to pasture decline (Reeve et al 2000). However, less than 20% of producers surveyed thought grazing management was important in maintaining desirable composition, but 82% thought that grazing management was worth doing to achieve desirable species composition (Reeve et al 2000). Little acknowledgement has been given to the grazing management as a contributing factor to this decline (Kemp & Dowling 2000).

Poor grazing management is often the result of endeavours to increase enterprise profitability by increased stocking rate or the resistance to implement grazing management that may be seen as labour intensive or requires investment in additional infrastructure. A stocking rate that is sufficient to utilise spring growth is always in excess of the maintenance potential of the summer and autumn periods. The decline of perennial species from failed grazing management has a negative impact for a wide range of landscape management and sustainability indicators. For example, the decline of perennial species favours the proliferation of annual species and these have contributed to the net gain of soil water (Hatton and Nulsen 1999), and increased the risk of dryland salinity. Additionally, a reduction in perennial species decreases biomass groundcover, increasing water runoff, and the export of nutrients and soil particles.

A major challenge for the grazing industries is to reverse these trends in pasture decline and concurrently maintain economic sustainability. Ridley and Pannell (2005) identified that systems based on perennial species was one option to manage dryland salinity on the condition that they were economically competitive with annual based systems. The EverGraze project (Masters et al 2006), is undertaking these challenges through the implementation of summer active perennial pasture systems that overcome landscape degradation and significantly improve farm profit. In particular, increasing the summer activity of pastures could deliver improvements in farm profit by 200-400% (J.Young *pers. comm*.).

4.2 Summer active pastures

Summer active pasture species can provide feed supply during the summer autumn deficit. In general these species have root systems that can utilise available water from deep in the soil profile and because they are active during summer and autumn, they can utilise rainfall events that occur during these periods that would normally escape dormant perennial or senescent annual species. In addition, these root systems allow them to survive the summer dry period better than winter active perennial species. However these species do required separation and placement to specific soil types and topography. For example, Lucerne (*medicago sativa*) has to be planted in free draining soils, usually higher in the landscape, and cannot tolerate a high level of aluminium. However, species like Kikuyu () can be planted in areas that undergo water logging and perform well in lower parts of the landscape.

Management of these pastures is also radically different for grazing and nutrient balance. Lucerne requires a medium level of tactical or rotational grazing (Ransom 1982), although more grazing tolerant cultivars are becoming available. Lucerne also fixes atmospheric nitrogen and after several years, accumulation of nitrate in the soil profile will allow nitrogen hungry weed species to proliferate, unless a companion species that can utilise excess nitrogen can be incorporated into the sward. In contrast, Kikuyu can withstand and requires heavy grazing to promote new growth and maintenance of feed quality. If allowed to accumulate biomass, feed quality and animal performance will decline. Unlike Lucerne, Kikuyu has a requirement for nitrogen, and is planted with companion legumes that supply nitrogen while providing winter and spring biomass production when the Kikuyu is dormant.

These two examples of summer active species document the complexity of managing many interactions within the farm system and why uniform management and application of inputs will hinder their longer term viability. Flexible systems are therefore required to maintain these species in the farming system. Several authors have highlighted the importance of maintaining botanical composition and species richness within the grazing system (Sanderson *et al* 2004). However, the task is rarely achieved due to the complexity of managing the herbivore and plant species interaction and the plant-to-plant interaction under a production driven system. Tainton *et al* (1996) states, that where management can be controlled it is advisable to reduce the spatiotemporal heterogeneity of the system in order to simplify management and maximise production. Even for winter active species, Waller and Sale (2001) proposed that perennial ryegrass in south eastern Australia required flexible management, including combinations of grazing method and spelling, to achieve seed set and tiller production that would ensure survival over the summer months and maintain production.

In order to achieve these management criteria, and maintain the diversity in pasture species and associated environmental benefits, it is hypothesised that accelerated lambing systems can provide the flexibility to ensure appropriate management is undertaken by reducing total grazing pressure during low production potential stages and provide economic incentive through increased product output relative to input costs. Recent work completed in New Zealand utilising the STAR accelerated lambing system showed that there was minimal difference in the amount of forage consumed by ewes in the STAR system and conventional annual lambing (627 vs. 615 kg Dry Matter/ewe/year) (Meat and Wool New Zealand 2007). However, due to the mating structures employed, peak requirements for the STAR system were constant at 27 kg Dry Matter per day (DM/d), year round, whereas the conventional flock had a peak requirement of 42 kg DM/d during spring, and 18 kg DM/d per day during winter.

The benefits of accelerated lambing to the grazing system are not just constrained to the management of the forage system. Forage systems that increase the diversity of pasture species allow farming systems to be designed to exploit grazing behaviour and maximise intake and animal performance. In addition, pasture species that contain beneficial secondary compounds for animal production can be utilised that may have been compromised in previous conventional systems.

4.3 Grazing behaviour and plant secondary compounds

Exploiting the grazing behaviour of ruminants through preferences for different plant species has attracted attention in recent years. Preference can be influenced by the previous grazing history of animals on pasture, the availability of pasture, pasture species and duration and method of evaluating choice (Parsons *et al.* 1994; Rook *et al.* 2002). Increases in feed intake have been achieved by providing sheep a choice between adjacent monocultures of perennial ryegrass and white clover, compared to grazing these species as a mixed sward (Champion *et al*. 1998), and lactating dairy cows reported a 11% increase in milk production from grazing grass and clover side by side (Cosgrove *et al.* 2001).

In the context of accelerated lambing systems, the recent application of choice grazing systems between subterranean clover and perennial ryegrass appears to significantly increase the performance of the animal (Thompson 2006). In this study, crossbred ewes provided with a free choice between adjacent perennial ryegrass and subterranean clover monocultures, gained weight during late pregnancy and lactation. In addition these ewes reared twin lambs at individual growth rates in excess of 300 grams per day. It is generally accepted that ewes will lose weight during lactation, and this study has demonstrated that the negative energy balance may be avoided by maximising intake during this high demand period. The negative energy balance associated with the restriction of re-breeding at short intervals may be overcome using this technique. Likewise the requirement to wean animals at younger ages in accelerated lambing will only benefit from these systems where lamb growth rate is maximised.

Pasture species that contain secondary compounds also offer the ability to exploit grazing behaviour, intake and performance. Ramirez-Restrepo and Barry (2005) reviewed alternative forages containing secondary compounds and found that condensed tannin containing legumes such as *Lotus corniculatus* L., sulla (*Hedysarum coronarium*) and the herb chicory (*Cichorium intybus L.*) offered significant advantages. Condensed tannins reduce degradation of protein in the rumen and allow it to be bypassed to the abomasum where the lower pH environment allows its release. The advantages of these species include anthelmintic properties for control of internal parasites (Terrill et al 1992; Molan et al 2000), increases in ovulation rate and potential reductions in methane emissions (Ramirez-Restrepo and Barry 2005).

For accelerated lambing the benefits will be similar to those reviewed by Ramirez-Restrepo and Barry (2005), however of particular importance are the effects of protecting proteins for bypass into the abomasum that provides greater absorption of essential amino acids. The increased glucose supply is likely to be similar to the effect experienced from lupin flushing, but in addition, bypassing protein from the rumen would ensure that excess ammonia production would not compromise reproductive mechanisms.

Although accelerated lambing may provide a platform for the application of these concepts and the benefits to the animal system are equally complimentary, the ability to achieve these goals in on farm production systems will require significant management skill. The areas of both diet selection and intake, and utilisation of diverse plant species and secondary compounds, should be focus towards simple and adaptable mixtures and combinations of both species and management that can be integrated readily into existing farm systems. Similar to the grains industry, there is a need to determine strategies on how species can be cycled in and out of the farm system once the productive lifespan of the pasture has been reached and what combinations or rotations of species over the longer term will maximise production.

5 Conclusions

The level of research undertaken in accelerated lambing is significant, however consistent failings in reproductive success during the anoestrous period and at short lambing intervals is still a significant impediment to wider commercial adoption. Complexity of systems in both the animal and forage systems is a common theme and may well be greatest challenge for implementation. However the absence of suitable justification of these systems economically and at farm scale is a major limitation.

Currently it would appear that lambing frequencies based on 3/2 cycle should be achievable from a physiological standpoint. Understanding the reproductive biology will be the key to future development of accelerated lambing at shorter intervals, and industry should aspire to reach the target of achieving 6 monthly lambing intervals, but careful thought is required to identify the selection criteria that can easily be adopted by industry.

The application of mating structures requires careful consideration because they can improve selection pressure, but at the cost of increased complexity. There is a need for a flock structure that will apply selection pressure that can be easily simplified once animals with desirable traits are selected, or methodologies that can be employed in annual lambing systems that prepare for the transition to an accelerated lambing system. This should not be done in isolation of forage systems development and preparation of the feed base for accelerated lambing can be achieved immediately as benefit should be realised even with conventional annual lambing systems.

Forage systems that can support accelerated lambing appear to be progressing, particularly with summer active perennials and spatial distribution to land class undertaken in EverGraze project. More emphasis is required to how these systems can be practically managed to achieve the potentially large gains in exploiting animal preference and plant secondary compounds for improved animal and system performance.

The application of accelerated lambing systems in current Australian grazing systems requires further investigation, including:

1. Determine the sensitivity of whole farm profit to improvements in reproductive output, and what level of reproductive performance is required before accelerated lambing becomes more profitable than current annual lambing systems.

2. Determining the trade off between stocking rate and increased reproductive output of accelerated lambing systems on whole farm profit.

3. Determine the combination of lambing frequency and mating structure that will best match the forage system, with different proportions of opposing summer and winter activity.

4. Determine the ability of choice or novel pasture systems to reduce the negative energy balance during late pregnancy and lactation, and to improve the rate of re-breeding at short intervals.

5. Determine the role of secondary compounds, in particular condensed tannins, for their ability to provide improved glucose supply for increased ovulation rate.

The need to increase efficiency from an increasing number of environmental and economic constraints is likely to drive development in this area at some point in the future. The possible large gains from implementation of these systems may not be able to be ignored for much longer.

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