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Optimising ewe reproductive performance in containment areas

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Project team

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Executive summary

Due to recurring, often successive poor seasons, breeding ewes are increasingly being fed in containment areas before and during pregnancy. Reports on containment-fed ewes show generally 'normal' lamb marking rates, but they are variable with anecdotal reports of pregnancy rates < 50% to 95%. The reasons for this are unclear. Determining whether particular practices lead to reduced reproductive performance is an essential step in minimising risk and improving performance. Currently, the recommendations to industry for management of ewes when containment-fed are conflicting, and some are not evidence-based. This lack of understanding increases the risk of unnecessary costs, sub-optimal reproduction, poor ewe health and inferior welfare outcomes. The aim of this project was to identify feeding and other practices that could be managed to optimise reproductive performance whilst ensuring ewe welfare, and identify RD&A gaps.

The scientific literature was reviewed to clarify the evidence to support current practice and guidelines. The review included evaluation of pen design, ewe and ram husbandry, and feeding strategies during joining and of the pregnant ewe, with consideration of the optimal ewe body condition score. A focus group consisting of six producers/consultants knowledgeable in containment feeding, and the research team, was then conducted to consider industry experience regarding any impact of containment feeding on reproductive performance, define current producer practices, and to identify RD&A recommendations resulting from both the review and from industry experience. These recommendations were then prioritised by the research team based on industry and team assessments of priority, and including estimated industry impact, ease and cost of implementation, and risk. Where the review identified sufficient evidence, guidelines for managing ewes in containment were drafted into extension materials, and provided to MLA for further development and national distribution in key industry programs and websites. The findings of the project are being publicised to industry through media activities, and through submission to scientific forums.

This project has determined that the industry considers the reproductive performance of containment fed ewes to be generally satisfactory. Ewe welfare is improved due to frequent monitoring, and performance is anecdotally reported as better than that of ewes losing condition when given inadequate nutrition under poor grazing conditions. However, there are documented reports of 10% reductions in lamb marking rates associated with containment feeding, although it is unclear whether practices associated with containment management caused this. Such reductions are probably not noticed by producers, yet reduce profits. Incidents of substantially reduced reproduction or adverse health events, particularly but not always associated with acidosis, pregnancy toxaemia or disease, are recognised as occurring, although industry believed these are largely preventable with attention to management. Adoption of the updated guidelines may reduce the risk of reduced performance. However, there is minimal data defining what the optimal practices are, specific to containment management, and their impact on reproduction and ewe health. Further research is recommended to define optimal husbandry and feeding management.

Several researchable gaps associated with containment feeding were identified. The priority issues with potentially large impacts on ewe reproduction and health were, in order, defining: the optimum level of roughage; the maximum safe feeding level; the optimum mob size; the impact of shade; the optimum feeding method; condition score and feeding in late pregnancy to improve lamb survival; and managing shy feeders. The priority development/adoption issues were: ram management; introduction to feed; monitoring of ewes; removal from containment; and separation of different classes of sheep. Further research and adoption activities in these areas are recommended to assist producers to manage the health and reproduction of breeding ewes in containment.

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1 Background

Drought or low availability of pasture may require either sale of sheep, or hand-feeding for either short or prolonged periods. The current high value of sheep meat provides incentive for producers to maintain their flock of breeding ewes to generate future lambs and income. While the ewe flock could be maintained in their normal grazing paddocks, containment areas, where ewes are restricted to small paddocks or yards and are completely hand-fed, are recommended to minimise erosion of soils and to protect pastures, while maintaining sheep numbers (Lilley and Moore 2009) and potentially improving ewe welfare.

Numerous published guidelines for containment feeding are available (McFarland *et al.* 2006; Dickson and Jolly 2011; AWI 2017; DEDJTR 2018; Dickson 2020b), in addition to advice from service and retail providers. Some of the information is conflicting, and there is limited evidence to support some of the advice. This potentially leads to producers being confused as to what is best practice to optimise the reproductive performance of ewes, and may result in unnecessary expenses and increased risk to production and sheep welfare.

The scientific literature has previously been reviewed in relation to production feedlotting of lambs (Jolly and Wallace 2007), with industry priorities for lamb feedlotting (Hancock 2006; Dickson 2020a) and containment feeding (Bessen 2003) identified. However, any impact of containment management on the reproductive performance of ewes has not previously been specifically considered. Any reduction in lambs marked per ewe may reduce producer income, so identifying practices which optimise ewe reproduction, or reduce the risk to reproduction or ewe health, are of substantial benefit to the sheep industry. The aim of this project was, therefore, to identify, where possible, scientific evidence for best practice containment management of ewes during joining and pregnancy to optimise reproduction. This provides opportunity to improve the guidelines available to industry, and to identify priority areas for adoption activities, and define researchable topics where insufficient information is currently available.

2 Project objectives

1. Completed a literature review on the management of reproductive performance and optimised feed strategies for pregnant ewes in containment areas. A focus group to gather feedback from producers will also be undertaken.
2. Complete a draft journal article based on the literature review.
3. Developed (in consultation with the MLA Adoption and Communications teams) and provided to MLA extension materials reflecting guidelines for producers to optimise the feeding and management of breeding ewes in containment areas.
4. Completed and provided to MLA a final report documenting the relevant literature, current practices, researchable gaps, and a prioritised list of potential R&D or A activities for managing the reproductive performance and feeding of ewes in containment areas.
5. Delivered the findings of this project to the Graham Centre Livestock Forum, through media activities, and publish the findings on at least one producer-accessible website, including 3 producer case studies. Note this objective will not be complete until 31st July 2020.

3 Methodology

3.1 Literature review and focus group

A review of the scientific literature was undertaken to compare the current guidelines for containment feeding with the scientific evidence, to determine whether the guidelines were based on adequate evidence, and to identify gaps in knowledge. A focus group with the research team and invited producers/consultants was then conducted to seek industry perspective, and to define current industry practice. The research and adoption gaps identified were then prioritised based on estimated industry impact, ease and cost of implementation, and risk.

4 Results

4.1 Literature Review

A literature review has been completed and is presented below. It is the basis for a paper intended for publication in an international scientific journal (see Appendix 9.1).

4.1.1 Introduction

Periods of inadequate pasture availability result in the need to supplementary feed sheep. While sheep may be supplementary fed in the paddock, complete hand-feeding of sheep in containment areas (drought lots; group pens or small paddocks) to protect pastures and minimise soil erosion is recommended as an environmentally responsible and profitable option (Lilley and Moore 2009). However, containment feeding differs markedly from the typical extensive grazing systems used in Australia and elsewhere, so producers are seeking further advice on how to manage breeding ewes in these systems.

Guidelines for managing sheep in containment areas are available (McFarland *et al.* 2006; Dickson and Jolly 2011; AWI 2017; DEDJTR 2018), with the most recent by Dickson (2020b). These guidelines include aspects of pen design, feeding and animal health. However, it is not clear that all of the guidelines are based on adequate evidence, and some recommendations are conflicting. The guidelines also provide very limited advice specific to management of ewes during joining and throughout pregnancy. Achieving optimal rates of pregnancy and fecundity, and managing the pregnant ewe to minimise health issues and facilitate subsequent lamb survival and growth, are important objectives to achieve profit and welfare goals.

The purpose of this review was to evaluate the management used in containment feeding and identify optimal strategies for the welfare and reproductive performance of ewes during joining and throughout pregnancy. The lambing period was beyond the scope of this review. The review focused on husbandry, nutrition, feeding strategies and ewe condition score, as these are the key areas which can be managed.

4.1.2 Pen Design

Regulatory guidelines for pen design are provided elsewhere (Dickson and Jolly 2011), with the most recent Dickson (2020b), and the current review will focus on production impacts. Confining sheep in small areas, rather than paddocks, reduces activity in searching for feed and water, which reduces energy used by an estimated 20%, varying with steepness of land and distance travelled (SCA 1990).

Space allowance between 1 and 3 m^2 per pregnant ewe does alter behaviour (Averós *et al.* 2014), although it is unclear whether this would result in welfare or production impacts with large mob sizes. The Australian welfare standards require a minimum space of 1.3 m^2 for adult sheep, 1.4 m^2 for heavy wethers, and increasing to 1.8 m^2 for ewes with lambs for outdoor feedlots (Australia 2014). The guidelines do not provide a guideline for pregnant ewes in outdoor feedlots (group pens), although for single pens, they state 1 m^2 per ewe, which is higher than the 0.9 m^2 for dry ewes in single pens. The space allowance of 1.4 m^2 for heavy wethers in outdoor feedlots is consistent with experimental studies using wethers showing that increasing space allowance above 1.42 m^2 per wether did not reduce the incidence of sheep eating daily, but high rates of non-feeding occurred at lower space allowances. The welfare standard is also above the minimum 1.2 m^2 reported to optimise weight gain in sheep under hot environmental conditions (Dundon and Mayer 2015). The 1.8 m^2 required for ewes with lambs is lower than the 5 m^2 recommended for sheep in general to enable better access of all sheep to shade, feed and water (DEDJTR 2018), but that recommendation does not appear to be based on experimental data. A space allowance of 2 m^2 per sheep was previously recommended to reduce dust, based on a survey of producers (Morbey and Ashton 1990), although it may be expected that larger pens would become less muddy in wet conditions. Pen size may also be influenced by the feeding system and need for vehicle access. However, producers frequently use larger space allowances than required (Morbey and Ashton 1990), so pen size appears unlikely to be limiting reproductive performance.

Pen design is important in allowing different classes of stock to be separated, to provide ease of feeding, and to minimise risk of injury to both sheep and operators. While various designs are provided in the current guidelines, a range of designs appear to result in adequate performance, and there is no evidence that any particular formation is superior.

While some guidelines state that provision of shelter is not necessary (AWI 2017), the most recent guidelines state that shade or shelter should be used to minimise the impact of poor weather (DEDJTR 2018). The latter reflects the Australian welfare standards which require protection of sheep from heat and cold stress (Australia 2014), and the implication that it should be sufficient to protect all sheep in the containment area. The need for shelter will depend on the time of year, so probable weather conditions, when sheep are containment-fed should be considered. In a review of heat stress, Sevi and Caroprese (2012) cite the thermoneutral zone of sheep as 5 to 25°C. They cite studies showing that heat stress can reduce immunity levels, cause mineral imbalances, reduce feed intake, and may reduce rumen function. Heat stress can also reduce the reproductive rate from sheep (van Wettere *et al.* 2019), as discussed later. Provision of shade can reduce the incidence of heat stress in sheep, although adequate ventilation is also required. Where cool temperatures may remove the need for shade to protect sheep, provision of shade may have the potential to prevent pens drying as quickly, potentially increasing mud and the risk of disease transmission. Whilst outdoor containment areas cannot protect sheep from cold, provision of structures to reduce wind speed can reduce wind chill, and so reduce any increase in feed requirement due to cold weather (SCA 1990).

Month of shearing should also be considered when calculating the need for shelter. Solar radiation is the source of much of the heat, and insulation due to an increasing fleece length up to 4 cm reduces the respiration rate of sheep exposed to radiant heat (Parer 1963). However, the value of fleece length varies. Under hot but humid conditions (33°C dry bulb temperature; 55% relative humidity), recently shorn sheep are able to maintain lower body temperatures than those with > 8cm of wool (Beatty *et al.* 2008). Timing shearing to avoid very short wool during hot months is therefore recommended to minimise heat stress only in low-humidity environments, although other factors will also determine the optimum month of shearing. Shearing date and removal of the insulation provided by the fleece will increase feed requirements in cold weather, and may increase the risk of exposure in poor weather. Shearing in June rather than October increased the feed requirement for June to August of non-breeding sheep by 66%, but by only 18% for July-lambing ewes, due to the increased heat production of ewes during late pregnancy (Black and Bottomley 1980). However, shearing date should also be considered regarding the need to avoid stress in ewes in the weeks pre-lambing to reduce the risk of pregnancy toxaemia (Schlumbohm and Harmeyer 2008), wool length during lambing, and dust or mud contamination of long wool due to confinement in containment areas.

Provision of adequate water is essential both for welfare, and to avoid reductions in productivity, and this has been reviewed elsewhere (Chedid *et al.* 2014). Under hot conditions (40°C), water turnover in sheep grazing arid-zone herbages (mainly chenopods) may be 173.4 ml/kg liveweight, or 8.7 L/day for a 50 kg sheep, although individual sheep may require larger quantities (Dawson *et al.* 1975). Water requirements increase for late pregnancy and lactation (SCA 1990). Water consumption will be lower under milder weather conditions, and if the water content of feed is increased (SCA 1990). While the intake of water is higher as ambient temperature increases, in hot temperatures sheep prefer to drink water of 30°C, rather than 20°C (Savage *et al.* 2007). The drinking of water which is cooler than body temperature also does not remove heat from the body as efficiently as evaporation (SCA 1990). While there may be benefit in burying pipes to prevent water becoming very hot, it appears both impractical and with minimal benefit to attempt to provide water markedly cooler than the environment to sheep.

Previous literature has provided varying unsubstantiated evidence as to what is the optimum length of water trough (Jolly and Wallace 2007). Experimental studies in feedlots showed an optimum of 1 cm per sheep for sheep fed pellets, although that study occurred during mild temperatures and only 60 to 100 sheep per pen, using wethers with an average weight of 45 kg (Dundon and Mayer 2015). For larger mob sizes of up to 500, the previous recommendation has been for 30 cm + 1.5 cm per sheep of single-sided trough (McFarland *et al.* 2006), so it seems that at least in milder conditions, this is more than optimal. Flow rate may be more important than trough length (DEDJTR 2018). Trough length for water is probably less important than for feeding, as water should be replenished until all sheep have consumed adequate, or be freely available.

While with *ad libitum* feeding trough length may be less important and 5 cm per sheep has been considered adequate, where sheep are fed a maintenance ration, insufficient trough length for feeding may result in some sheep not gaining access to the feed (Jolly and Wallace 2007). However, optimum trough length may also vary with frequency of feeding, with less frequent feeding (compared with daily) requiring lower trough length as all feed cannot be consumed quickly. More recent experiments indicate that 10 cm per sheep is the optimal trough length for near *ad libitum* fed sheep (Dundon and Mayer 2015). Under experimental maintenance conditions using wethers, a trough length of less than 4 cm per sheep reduced the percentage of sheep eating daily from 77 to 95% to 37 to 74% (McDonald 1986). For outdoor containment feeding, a minimum feed trough length of 15 cm per sheep for double-sided access has previously been recommended, increasing to 20 cm for sheep with long wool length, based on a survey of producer experience (Morbey and Ashton 1990). However, more recent experimental studies in the Persian Gulf have shown that for maintenance feeding rates for 45 kg wethers, a minimum 5 cm was required, with no further increase in carcase weight at trough lengths of 10 or 15 cm per sheep (Dundon and Mayer 2015). However, the optimum may be higher than 5 cm for larger ewes, and this has not been determined. The placement of troughs along fencelines, rather than in the centre of pens, has reduced the percentage of sheep feeding initially, but not after 7 days (McDonald *et al.* 1990), although it was not clear whether trough length (double-sided versus single-sided access) contributed. Producer experience indicates that raising feed troughs to 30 cm height may reduce dust and manure contamination (Morbey and Ashton 1990), although producers have successfully fed at ground height troughs or by using trails on the ground (Ashton and Hannay 1984). The need for troughing may depend on the soil type (hard surface needed), weather conditions (rain and mud increase trampling and contamination of feed if troughing is inadequate) and duration of feeding. Both feed and water troughs need to be cleaned as often as required, which may mean daily under some conditions (Ashton and Hannay 1984).

Water quality is also important. Water can reduce productivity or cause death if excessively contaminated from bacteria associated with manure or decomposing plant material, excessive nitrogen levels, toxic algae, or chemical residues (Carson 2000). In containment areas, dams may be prone to contamination due to the high stock density, and wind movement or washing of materials into the water. They may also pose a risk of bogging as water levels become low. Trough systems can be regularly cleaned. The salt content of water should be monitored, particularly for bore water. Water with a salt concentrations of 1.3% NaCl is suitable for non-breeding sheep, but higher salt intakes can reduce feed intake, and may reduce lamb survival for twin-bearing ewes (SCA 1990). However, the concentration of magnesium salt also determines suitability for different classes of stock, with excess concentrations reported to reduce the proportion of ewes lambing. Maximum tolerable levels for saline water are shown in Table 1.

Pen enrichment of indoor-housed feedlot lambs, by provision of a ramp and cereal straw as bedding/forage, reduced measures of stress and improved daily growth rates from 305 to 361 g/day (Aguayo-Ulloa *et al.* 2014). However, that study was conducted indoors, which may be a more stressful environment than a typical outdoor containment area used for mature ewes. It is unclear whether the result was due to nutritional benefit, or the ramp providing enrichment. In addition, lambs may behave differently to adult ewes. It is therefore unclear whether pen enrichment could improve the performance of ewes in containment areas.

Recommendation
It is clear that the current guidelines around space allowances and trough lengths can be updated using more recent information, and to comply with welfare guidelines. More detail on considerations of shade and shearing date may also be of value to producers.

Table 1. Total soluble salt and magnesium concentrations (ppm; where mg/L=ppm) in water and suitability for sheep (source: SCA 1990)

Total Soluble Salts (ppm)	Magnesium (ppm)	Sheep
>4500	<250	Not suitable for lambs
4500-6000	<250	Suitable for lactating ewes
6000-15000	<500	Suitable for non-lactating adult sheep

4.1.3 Management of ewe reproductive performance in containment areas

4.1.3.1 Is reproductive performance of containment fed ewes suboptimal?

Reproductive performance is indicated by fertility (pregnancy rate), ovulation rate or fecundity (number of lambs per pregnant ewe), embryonic and fetal mortality, mortality of lambs from lambing until weaning, and ewe mortality. Each of these factors is potentially the most important source of loss for individual flocks. Under grazing conditions, perinatal mortality of lambs is the largest source of reproductive wastage (Kleemann and Walker 2005b). There is limited literature defining the reproductive performance of containment-fed ewes under commercial conditions, and less defining the timing of wastage.

Anecdotal reports for containment-fed ewes indicate a range in pregnancy rates < 50% to 96%. This is supported by experimental data indicating a pregnancy rate of 43% for ewes in a containment area fed wheat at a rate of 700g/ewe per day, plus roughage, although the cause of the low pregnancy rate was unknown (Robertson and Friend 2020). The range in pregnancy rates is consistent with reports from presumably paddock joinings (Kleemann and Walker 2005b). Data from deferred grazing comparisons, where ewes were containment-fed for a period of pregnancy, and lambed on pastures, indicate containment feeding had a variable impact on lamb marking percentages, with a +7 to -14% difference compared to ewes set-stocked on pastures (Hunter and Whale 2019).

Analysing data on reproductive performance for containment fed ewes is difficult, as rarely is it compared with non-containment-fed ewes under similar feeding conditions. Given containment feeding is normally applied when paddock feed availability is already limiting and the condition score or bodyweight of ewes is often below “normal” conditions, reports of lower pregnancy rates during containment feeding are to be expected. Containment feeding could also be expected to result in higher pregnancy rates than if ewes remain in paddocks if the level of nutrition is superior, which also would be expected under drought conditions. However, there is evidence that performance may be reduced. Two case reports for ewes containment fed throughout joining, but not lambing in containment, indicated 96% lambs marked per ewe joined, which was less than the 117% for ewes maintained in paddocks, and 106% for containment-fed compared with 112% for grazed ewes, although it is not clear whether the nutritional levels were similar (Ashton and Hannay 1984). This is consistent with results from Minnipa, with 74% lambs marked for containment fed ewes, and 85% for those grazing crop stubbles (Morbey and Ashton 1990). A survey of producers who containment fed pregnant ewes on Eyre Peninsula during 1988 found that while on average the lamb marking percentages (79%) were similar to the regional average for 1984, 18.9% recorded less than 70%, and 3.8% recorded less than 55% (Morbey and Ashton 1990). It is not known what proportion of those farms joined ewes while in containment areas, and the comparison with a different year may overestimate any impact of containment-feeding. The point at which the reproductive failure occurred was not determined in any of these reports. However, it is clear that suboptimal levels of reproduction are common, and that therefore, there is potential for improvement.

The data suggest suboptimal rates of reproduction may sometimes result from containment feeding and can be substantial. Importantly, relatively small reductions (10%) may not be detected by producers, or may be dismissed as normal seasonal variation, yet these have a large impact on production and profit nationally. This hidden wastage and lack of direct comparison may mean that suboptimal practices have not been identified. Further investigation to define the level, frequency and causes of reproductive wastage specific to ewes in containment management systems is warranted.

4.1.3.2 Ram management

The current guidelines on containment areas give sparse recommendations for ram and joining management (DEDJTR 2018). Optimal pregnancy rates depend upon ram as well as ewe performance. Under paddock conditions, a pregnancy rate of 90 to 95% is commonly achieved (Kleemann *et al.* 2006; Allworth *et al.* 2017), although lower rates are reported in drought years (Fowler 2007). Under paddock conditions, increasing the percentage of rams used between 1.27 and 3.68% has not increased pregnancy rates for either adult or maiden Merino ewes (Kleemann *et* *al.* 2006), although other reports indicate fertility may be improved for maiden ewes if ram percentages above 1% are used (Fowler 1976). Some studies indicate that the percentage of ewes joined conceiving twins is increased by 5-7% when the ram percentage increased from 1 to 2% (Lightfoot and Smith 1968), although this effect may have been influenced by the use of 1.5 year old rams. Such an effect was not observed by Kleemann *et al*. ewes (2006). However, survey data from commercial properties has indicated a 16.8% higher twinning rate for non-Merino, but not Merino, ewes joined in mixed-age mobs to ≥2%, rather than <2% rams (Allworth *et al*. 2017). This may reflect a breed difference in competition between inexperienced and mature ewes, so that ram numbers are more efficiently used by joining maiden ewes in separate mobs.

There is no data for containment areas, but it is probable that similar percentages of rams are used as for paddock matings. This indicates that some producers may be able to reduce the number of rams used, providing rams are healthy. One exception is if the length of joining is reduced and ewes only have one opportunity to mate, where ram percentages above 1% have the potential to increase pregnancy rates. Another exception is where ewe lambs are mated, as failure to mate, possibly due to poor expression of oestrous behaviour, is one key cause of poor performance (Edwards *et al.* 2016). The fertility of ewe lambs has increased with ram percentages of 2%, particularly for the first 17 days of joining, although in some years a benefit has been observed over the entire 34 day joining period (Kenyon *et al.* 2010).

The number of rams used should also be considered in regards to the size of ewe mobs in containment areas. Firstly, for adult ewes a ram percentage of 1% + 1 additional ram for each adverse factor is recommended (Fowler 1976), so larger mob sizes use rams more efficiently. Secondly, a proportion of rams are infertile or have low mating activity (Fowler 1976), so mating with single rams is not recommended for commercial flocks. A range of factors alter the mating performance of rams and have been reviewed by Tilbrook and Cameron (1990). Dominance of rams is one factor. If the dominant ram is infertile, the pregnancy rate of ewes may be reduced. Fowler and Jenkins (1985) using mobs of 100 ewes and 3 rams, showed that using an infertile dominant ram reduced pregnancy rates from 90 to 72%, although pregnancy rates were not reduced if subordinate rams were infertile. In contrast, in containment feeding areas, pregnancy rates of over 90% have been achieved when mating 200 ewes to a group of 3 rams comprising high and low sexual activity, and homosexual (Stellflug *et al.* 2006). However, the high activity ram in each group on average sired 46% of the lambs born. The dominance or activity level of rams is probably more important where smaller mobs of ewes are used with few rams. Close proximity may be required for dominant rams to restrict the mating of subordinates (Mattner *et al.* 1967). Any impact of dominance may therefore be more apparent when ewes are joined in containment rather than paddock situations, due to potentially smaller mob sizes and number of rams being used. No studies have been found which indicate whether there is an optimum mob size for joining in containment areas.

The level of nutrition in the weeks prior to joining alters ram performance. Sub-maintenance levels of nutrition resulting in weight loss of ≥ 4% liveweight per month reduce both sperm production and quality (Parker and Thwaites 1972) and libido (Mattner and Braden 1975). Muscle weakness resulting from undernutrition has been associated with a greater number of failed attempts to mate, and failure to ejaculate (Parker and Thwaites 1972). The condition score (Jefferies 1961) was not reported but could be considered low since rams weighed < 45 kg. Sperm production is increased by improved nutrition, and providing energy supplements for 49-50 days pre-mating will increase sperm as well as liveweight in Merino rams (Fowler 1976; Murray *et al.* 1990), although this may be ineffective in British breed rams outside of the natural breeding season (Hotzll *et al.* 1994). Supplementing with 500 g/day lupin grain is effective although the response is not specific to lupins (Oldham *et al.* 1978). As for ewes, rams need to be introduced to grain feeding, other than lupins, gradually to avoid acidosis. There is no data defining any subclinical effects of acidosis on ram fertility, but any reduction in libido can be expected to reduce mating activity, so particular care should be taken to avoid acidosis in rams. Due to prolonged drought conditions and lack of access to green feed, or feeding of deficient diets, liver stores of vitamin A may decline, resulting in abnormal sperm (Sapsford 1951). If rams have not had access to green feed or green hay for more than two months, supplementation with a source of vitamin A is recommended (SCA 1990).

Overnutrition may reduce the mating dexterity of rams (Tilbrook and Cameron 1990). While the recommendation is to join rams in good but not fat condition score (Fowler 1976), the effect of condition score on reproduction in rams is poorly quantified. A condition score of 3 is associated with higher sperm production than for rams in score 2.5, while sperm production appears to decline for rams in condition score 4, which is associated with an increase in plasma cortisol concentrations (Maurya *et al.* 2010). There is some evidence that exercising rams to improve fitness prior to joining may increase pregnancy rates, with a 16% being recorded in one experiment, although this occurred without a change in ram weight (Combrink and Schoeman 1993). Therefore, management of rams to achieve optimal condition and sperm production for joining needs to occur at least two months before joining. The current guidelines that rams should be in condition ≥ 3.5 at joining, and be fed the same diet as ewes for three months prior to joining (DEDJTR 2018), need revision.

The duration of joining under Australian paddock conditions is typically 6 to 8 weeks (Allworth *et al.* 2017). The percentage of ewes pregnant does increase for joining durations between 6 and 8 weeks for the January to March period, with more variation in pregnancy rate at the shorter joining (Kleemann and Walker 2005b). Earlier joining outside the natural breeding season uses the ram effect, with most ewes not displaying oestrus until 18 or 25 days after introduction of rams (Martin *et al.* 1986). This necessitates an approximate 6 to 7 week joining period to allow ewes two opportunities to mate when joined outside the natural breeding season, whereas 5 weeks may be adequate for autumn-mated ewes. A joining period of only 1 oestrous cycle (17 days) has been reported to result in > 70% of ewe lambs pregnant (Kenyon *et al.* 2010). However, short joinings risk a large proportion of ewes not being pregnant if reproduction has failed, and ewes are not remated, and the risk is increased if inadequate rams are used. Even if pregnancy scanning detects non-pregnant ewes, the delay in remating may cause substantial disruption to the production system, so very short joining periods increase production risk. However, if ewes are to be fed during late pregnancy or lactation, the quantity fed is more efficiently provided with a short duration of joining. Containment feeding may facilitate the teasing of ewes to synchronise oestrus, by penning of rams in adjacent yards, thereby reducing the duration of joining. Ram harnesses may be used to identify then separate ewes which mate later, as a means of more efficiently identifying and feeding ewes separately as feed requirements increase during late pregnancy and lactation. Fetal aging by ultrasound at pregnancy diagnosis is an alternative method of separating ewes on gestational age, although dependant on the skill of the operator (Bunter *et al.* 2018).

Shearing of rams with an annual fleece has not increased libido (Mattner and Braden 1975). However, a short fleece reduces heat stress under dry heat in Merino sheep (Parer 1963), and has been suggested to improve mating dexterity (Fowler 1976). Short fleece also reduces the risk of flystrike (Wardhaugh *et al.* 2007), for which there may be an increased risk for rams during joining due to fighting (poll strike) and fluid accumulation around the pizzle (belly strike). Rams appear to find woolly ewes more attractive than ewes with 11 weeks or less wool growth, so it is advised to join recently shorn ewes in separate groups to woolly ewes to avoid potential reductions in fertility (Tilbrook and Cameron 1990)

Heat stress has the potential to reduce the fertility of rams, and has been recently reviewed (van Wettere *et al.* 2019). A reduction in fertility is likely when the temperature of ram testes increases to 39.5^{o}C (Fowler 1976), and scrotal temperatures are likely to be increasing when air temperatures are above 35 °C (Fowler and Kennedy 1968; Fowler 1969). Even under mild temperatures, provision of shade reduces ram scrotal temperatures (Teodoro *et al.* 2013). However, if shade is designed to limit the escape of hot air, it can prevent rams cooling during the night (Tharwat *et al.* 1991). Merino rams with high scores for wrinkle are more susceptible to heat-induced infertility (Fowler and Dun 1966), so selection for heat tolerant sheep is another strategy to improve reproduction when joining in hot conditions. Selection of Merino rams for genetically higher fat levels and reduced muscle may also reduce liveweight loss of flocks under poor nutritional conditions (Rosales Nieto *et al.* 2013).

4.1.3.3 Ewe management for joining in containment areas

4.1.3.3.1 Age of ewe

In ewes joined as lambs, failure to mate, low ovulation rate and embryonic mortality are key causes of poor reproductive performance (Beck *et al.* 1996; Edwards *et al.* 2016). A shorter duration of oestrus and reduced mating behaviour contribute to failure to mate (Restall 1976). The return to service rate for maiden ewes increases as the percentage of mature ewes in the mob increases, so ideally they are mated in a separate mob (Restall 1976). Additionally, the liveweight of maiden ewes is probably lower than that of adults, requiring a lower quantity of feed for maintenance, so it may be more efficient to feed in separate pens.

4.1.3.3.2 Mob size

The optimum mob size to join containment fed ewes is not clear. In wethers, Round (1976) cites the data of Arnold which indicated that space allowance but not mob size influenced stress levels. Low ewe mob sizes (40 ewes) have achieved a 90% pregnancy rate (Kennedy and Bettenay 1950), while satisfactory pregnancy rates are implied by a 96% lambs marked/ewe joined for a mob of 517 ewes (Ashton and Hannay 1984). However, direct comparisons of the impact of mob size on pregnancy rates have not been made.

The structure of mobs within pens may be important. Arnold and Maller (1974) found that 1 year old and 7 year old wethers were less competitive at feed troughs than intermediate ages, and that Merino sheep were less competitive than other breeds. These results indicate that it may be advisable to separate different breeds, immature and aged groups when containment feeding ewes, although there is no experimental evidence proving an adverse effect.

4.1.3.3.3 Heat stress

Heat stress can reduce mating activity, fertility, embryo survival, lamb birthweights and perinatal survival, as reviewed by van Wettere *et al*. (2019). The estimated impact was a 0 to 22% reduction in lambs born per ewe mated in the October to March period in Australian flocks, varying between locations with the incidence of hot weather. Both heat and cold or rain may also reduce mating activity and/or ovulation rate (Dobson *et al.* 2012). Under field conditions, temperatures above 32°C (Lindsay *et al.* 1975) or 35°C (Kleemann and Walker 2005a) are associated with lower pregnancy rates in ewes. Provision of shade-trees and iodine has increased the pregnancy rate of ewes from 57 to 73% for a summer joining in tropical semi-arid Queensland, although it isn't clear which factor was important, and the study did not use replicated groups (Hopkins and Pratt 1976). To reduce the risk of lower pregnancy rates, provision of adequate shade for ewes joined in containment areas is recommended. However, the impact of shade on the rate of reproduction under field or containment conditions is currently unknown. An alternative is to change the month of joining to avoid months of hot temperatures, but the full implications of this need to be considered. Genetic selection for more heat resilient animals may also be possible.

4.1.3.3.4 Ewe liveweight or condition

Body condition is an indicator of long-term nutritional status (Jefferies 1961). In extensive systems, the risk of ewe mortality is increased for ewes in condition < 2 (Doughty *et al.* 2019). For welfare reasons, ewes should be managed to avoid such low condition. However, understanding reproductive response requires definition of where production is altered.

The liveweight or condition of ewes at the time of joining influences both ewe fertility and the number of ovulations. Below a threshold liveweight of approximately 40 kg in Corriedale, Romney and Merino ewes, pregnancy rates rapidly decrease (Coop 1962; Killeen 1967; White and Ternouth 1970). The critical weight will vary with frame size. Above this weight the rate of non-pregnant ewes is relatively static at 4-8% (Coop 1962). Data from Romney and Composite ewes also shows no increase in pregnancy rates when ewes were above a condition score of 1.5 (Kenyon *et al.* 2004). Mating ewe lambs may require higher minimum condition targets. Romney composite ewe lambs in condition score 1.5 were less likely to be mated than lambs in condition ≥ 2, and 7% more lambs in condition 2.5+ became pregnant than those in condition 2 (Kenyon *et al.* 2010). Maximum pregnancy rates in non-Merino ewe lambs have been reported at a condition score of 3.5 (Corner-Thomas *et al.* 2015).

The number of lambs produced depends on fetal number per ewe, in addition to pregnancy rate. Edey (1968) reported a 2-4% increase in ovulation rate per kg liveweight above 35 kg for Merino ewes. Ovulation rates in Merino and Border Leicester x Merino ewes increase up to at least an estimated condition score 3, although possibly not above score 3 in some strains of Merino (Cumming 1977). Twinning did not increase further for Romney ewes above condition score 3, or for composite ewes above condition score 2, indicating no advantage to reproductive rate in maintaining ewes at higher condition scores (Kenyon *et al.* 2004). The number of lambs scanned per ewe may also be reduced for Romney ewes in condition score ≥4.5, so that mating in high condition score need not result in more lambs weaned per ewe (Tait *et al.* 2019). However, other reports indicate an increase in the number of lambs born per mature ewe joined from condition score 3 (1.11), 3.5 (1.26) to 4 (1.38), for Merino and other breeds (Gonzalez *et al.* 1997). Other studies suggest a linear increase in the number of fetuses scanned per ewe joined of 1.7 to 2.4 additional fetuses per 100 ewes for each 1 kg increase in ewe liveweight at joining, for Merino ewes with liveweights 35 to 65 kg (Ferguson *et al.* 2011). These data indicate there may be a variation in reproductive response between breeds and strain.

The optimal condition score may also be lower for adult ewes than for those joined as lambs. For non-Merino ewe lambs, the maximum number of fetuses per ewe joined has been achieved at a condition score of 3 (Corner-Thomas *et al.* 2015). Kenyon *et al*. (2014) have reviewed the impact of condition score on reproductive performance, and concluded that the relationship between condition score and reproduction is curvilinear, and with a decline in production in some breeds at high condition scores. They recommend separation of ewes to more efficiently feed those below a minimum condition score, rather than the whole mob. This would also prevent overfeeding of those in high condition scores, which may reduce reproductive rates. Feeding above maintenance levels to heifers in condition score 3.7 restricts embryonic development, while for those in condition score 2, improved nutrition is beneficial to embryos (Adamiak *et al.* 2005). Separate feeding to amend condition scores needs to occur well before joining, and the ability to achieve this practically may be limited by time constraints for identification and separation of individuals where mob size is large.

The nutrition of ewes six months before mating may also influence ovulation rate. Nottle (1997a) showed that ewes which lost 10 to 20% of liveweight six months before ovulation, but had regained their initial weight, had a lower ovulation rate (1.06) than ewes maintaining weight (1.28). Both groups produced 1.6 ovulations/ewe if flushed with lupin grain premating. In addition to the direct effect of liveweight at joining, this response contributes to the effect of nutritional management during one pregnancy on subsequent reproductive performance in the following year (Ferguson *et al.* 2011). These data indicate the need to manage ewe nutrition well in advance, as well as during joining, to optimise reproductive rates.

4.1.3.3.5 Feeding management

Even ewes which have minimal previous exposure to handling and containment will quickly adapt to containment feeding (Kennedy and Bettenay 1950). However, a percentage of ewes will not adapt to feeding, particularly of grain, and so will lose weight. Managing these shy feeders is critical to avoid loss of production and deaths. Shy feeders occur at a proportion of 5-7% even with small mob sizes (40 ewes/pen) (Kennedy and Bettenay 1950). Rates as high as 18% have been reported for Merino lambs with 40 lambs/pen, and a lower initial liveweight does not distinguish these lambs (Rice *et al.* 2016). Shy feeders need to be removed and fed in a separate pen or placed in paddocks to prevent continued weight loss. However, there is little evidence defining the optimum means or frequency of identifying shy feeders so that they can be removed.

A period of adaptation occurs after introduction to feed, with up to 70% of lambs not consuming the ration during the first 5 days after introduction (Bowen *et al.* 2006). Exposure of lambs to supplementary feeds while with their mothers (imprint feeding) improves intake of that supplement even 34 months later (Green *et al.* 1984). Therefore, imprint feeding of lambs is recommended to increase the rate of adaptation to containment feeding as adults. Furthermore, it is advisable to avoid joining ewes during the period of adaptation to feeding, when some ewes may be losing weight or experiencing digestive upset, as nutritional change over short periods of four days can alter ovulation rate (Stewart and Oldham 1986), apparently as a response to energy supply to the ovary (Vinoles *et al.* 2005). Ewes which were losing weight at 93 g/day had lower ovulation rates than those slightly gaining (48 g/day) in the 8 weeks before mating (Leury *et al.* 1990). In addition, sub-maintenance nutrition can cause embryo mortality (Edey 1970; Abecia *et al.* 2015). Where mortality occurs between 20 and 30 days of gestation, this may result in a 57% reduction in pregnancy rates at the next mating (Sawyer and Knight 1975). It may also cause failure to mate if return to service is delayed and occurs after the rams have been removed.

4.1.3.3.6 Type of feed

A wide variety of feeds may be fed to sheep. The average nutritive value of a range of common and novel feeds is published elsewhere (DEDJTR 2018). The variability in nutritive value within feeds indicates the value of analysing feed to more accurately calculate the quantity to feed. Uncommon feeds may be used in rations for ewes, but their optimum inclusion rate and data defining their impact on reproductive rates in ewes has not been studied.

Containment rations comprising only roughage are suitable for sheep if the quality is sufficient to allow maintenance levels of protein and energy (Franklin *et al.* 1967). Straw alone contains insufficient protein and energy levels to maintain weight, but may be adequate for mature non-pregnant sheep if better quality roughage or grain is fed in addition (Franklin *et al.* 1967). Lupin grain can be safely fed to sheep without roughage as it has a lower risk of causing acidosis than other grains (SCA 1990), although some introduction to high levels may still be required. Wheat has a higher starch content than barley or oats (Rowe *et al.* 1999), so a higher risk of acidosis. Diets of wheat only have been shown to be adequate for maintenance feeding of adult ewes during pregnancy (Clements *et al.* 1979), and for weaners if vitamin or mineral deficiencies are corrected (Franklin *et al.* 1955). However, diets comprised only of wheat grain have an increased risk of acidosis (Warren *et al.* 1988). Percentages of wheat chaff in wheat grain diets of 10 to 50% have proven adequate for maintenance feeding of wethers (Franklin and Sutton 1952). However, 20% roughage in the diet has been suggested as the optimum (SCA 1990). Rations comprising a lower quantity of roughage are also consumed more quickly (Sari *et al.* 2018), increasing competition for feeder space (Clements *et al.* 1979). Less frequent feeding intervals (less than daily) allows all sheep access to sufficient feed (Franklin and Sutton 1952).

Feeding straw rather than hay reduces the number of poor doers (shy feeders) (Morbey and Ashton 1990). Feeding hay at 0.5 to 1 kg/ewe per week, fed before the grain ration, resulted in 18 to 25% of ewes losing >7 kg over 13 weeks. In comparison, ewes fed 0.7 to 2 kg straw prior to the grain ration, had 0 to 8% ewes with > 7 kg weight loss. The authors hypothesised that the rapid consumption of hay meant not all ewes received their portion of roughage. Studies with wethers also showed the incidence of sheep failing to eat is increased by feeding processed, rather than unprocessed hay (Hodge *et al.* 1991). Processing of feeds is not recommended for sheep, as it increases the risk of digestive disturbance (Kirby and Beretta 2004).

There is limited evidence that any particular type of feed at joining results in better reproductive performance. When grazing abundant senescent pasture, supplementation with 0.5 kg/ewe/day lupins has produced more lambs born per ewe joined than ewes supplemented with the same quantity of either wheat or cut lucerne pasture (Kenney *et al.* 1980). However, in superovulated heifers, the number of viable embryos was reduced by feeding a diet based on barley grain compared with a diet based on citrus/beet pulp (Yaakub *et al.* 1999). Those authors suggested the more rapid digestion of grains caused the response, but the mechanism was unknown. Ewes pen-fed pea silage or a ration of pea silage (20%), cottonseed meal (8%) and oat grain (70%) at similar energy and protein contents, have produced a similar pregnancy rate (90%) and number of lambs born per ewe lambing (1.26) (Gulliver *et al.* 2013). Further investigation of any impact of type of feed at joining on reproductive rate is warranted.

4.1.3.3.7 Level of feed

The minimum energy and protein requirements vary with stage of gestation, and with frame size and liveweight of ewes. Table 2 indicates the maintenance energy requirement for ewes at mating then at particular days of gestation. The minimum crude protein requirement for adult sheep prior to late pregnancy is approximately 7%, with requirements increasing to around 12% during late pregnancy (SCA 1990). While these estimates can be used as a guide, condition of the ewe also influences maintenance requirements (Caldeira *et al.* 2007), so ewe condition should be monitored regularly for ewes in containment to ensure adequacy of feeding.

Maintenance feeding is recommended at joining for containment-fed ewes. Feeding well below maintenance (0.5 maintenance) causes embryo mortality (Abecia *et al.* 2015), and feeding at this level is not appropriate. In contrast, studies where ewes were fasted for 3 days within 12 days after mating showed that fasting single-ovulating ewes reduced pregnancy rates by 10%, but increased pregnancy rates in twin-ovulating ewes (Blockey *et al.* 1974). Even if effective, the inconsistent response and the need to restrict nutrition over the duration of natural joining makes such a strategy impractical, and sub-maintenance feeding is not recommended.

In pen studies, feeding at twice maintenance energy levels may also reduce embryo survival (Cumming *et al.* 1975), and has reduced pregnancy rates by 20% (Parr *et al.* 1987), although containment-fed ewes will probably not be fed this quantity. Both studies used a minimum 50% hay-based diet. The pregnancy rate was also reduced from 85 to 57% if 7-8 month old ewe lambs fed to grow rapidly rather than at 75 g/ewe per day, using a barley-based ration with 30% hay (Wallace *et al.* 1996), although not in adult ewes (Wallace *et al.* 2005), suggesting ewe lambs may be more sensitive to excess nutrition. Feeding at 1.5 x maintenance appears to reduce embryo quality in superovulated ewes (Kakar *et al.* 2005). In contrast, feeding a grass-based pellet at twice maintenance has not reduced pregnancy rates (Muñoz *et al.* 2008). Similarly, feeding 1.4 X maintenance energy levels of either silage or an oat-based diet has resulted in high pregnancy rates (≥ 90%) after a natural mating (Gulliver *et al.* 2013), although in another study using a similar quantity and type of feed, only 73% of Merino ewes became pregnant (Clayton 2014). Above-maintenance levels of feeding at mating can therefore reduce pregnancy rates, but the response is inconsistent.

Table 2. Minimum metabolisable energy (MJ ME/day) requirements of 50 or 60 kg frame size Merino ewes at different stages of pregnancy, not grazing. Calculated using SheepExplorer software (CSIRO)

	50 kg ewe		60 kg ewe	
Day of pregnancy	Single fetus (MJ ME/day)	Twin fetus (MJ ME/day)	Single fetus (MJ ME/day)	Twin fetus (MJ ME/day)
0	7.5	7.5	8.3	8.3
70	8	8.5	9	9.5
90	8.8	9.7	9.9	11
110	9.9	11.7	11.3	13.4
130	11.8	14.9	13.6	17.3
150	14.5	19.5	16.8	22.7

Studies without replication of groups found ewes in a containment area where the quantity of wheat was increased from maintenance at 0.5 kg/ewe/day to 0.7 kg/ewe per day during the second week of joining had a pregnancy rate of 57%, compared with 79% in ewes fed at 0.5 kg/day during early joining (Robertson and Friend 2020). Although this feeding level was not high, it is possible the type of grain or low level of roughage (10%) in the diet contributed to the poor result compared with earlier studies, although subclinical acidosis was not observed. While the condition score of ewes in both groups was 2.9, this was lower than the fat scores of 3.1 to 3.5 in the studies of Gulliver *et al.* and Clayton *et al*., so it is possible the fat level of ewes may also have contributed. The reasons for the variation between studies is unclear, but warrants investigation due to the high impact. Therefore, feeding above maintenance levels during joining is not recommended for ewes fed in containment areas until further studies show an increase in the number of lambs born. Most pen studies investigating nutrition use oestrous synchronised ewes and measure ovulation rate, not the number of lambs produced, and have inadequate numbers to assess pregnancy outcomes.

There is no information on flushing ewes to improve reproductive rates in the current containment-feeding guidelines. Short-term flushing targeting days 10-14 of the oestrous cycle (Stewart and Oldham 1986) can be used in naturally cycling grazing flocks by increasing nutrition for 7 days before and the first 7 days of joining (Robertson *et al.* 2014). In that study, up to 21 additional fetuses per 100 ewes joined were produced by grazing abundant live lucerne compared with grazing senescent pasture. For summer (out-of-season) joining, a two week period of feeding 500 g/ewe/day lupin grain from 12 days after the introduction of vasectomised rams, increased the number of lambs born by 14 per 100 ewes joined (Nottle *et al.* 1997b). Therefore, short-term increases in nutrition at joining for naturally cycling grazing ewes clearly can improve the number of lambs born, but the effect for ewes fed in containment areas is unclear given the variable effect of high feeding levels. Flushing should also be used only if the higher feed requirements of twin-bearing ewes in late pregnancy and lactation can be provided.

Various feeds have been assessed for flushing responses, and the ovulatory response is due to an increase in glucose supply and hormonal changes (Vinoles *et al.* 2005). Lupin grain has traditionally been used, and has the advantage of a low risk of acidosis. Attempts to increase the ovulation rates of grazing ewes with 0.5 kg/day per ewe wheat grain have not resulted in an increase, while 0.5 kg lupin grain increased lambs born per ewe joined from 92% to 113% (Kenney *et al.* 1980). Similarly, feeding grazing ewes 0.32 kg barley + 12 g urea per day has not increased ovulation rate, multiple births, or number of lambs born per ewe joined, whereas 0.23 kg lupin grain resulted in 7% more ewes lambing, 5% more twin births and 12% more lambs born per ewe joined (Knight *et al.* 1975). These results suggest that cereal grains may not be suitable feeds with which to flush ewes, although the reason is not clear. Ewes in both condition score 2 and 3 or 4 have shown the same increase (64%) in ovulation rate to short-term lupin supplementation (Pearse *et al.* 1994), although the number of ewes in that study was small. However, this data is consistent with earlier studies showing a response to increased nutrition for ewes estimated as < condition score 2, as well as those in higher condition (Killeen 1967). Other grazing studies clearly demonstrate that even ewes in optimum condition score (3.2) will respond with an increase in fetal numbers if flushed (Robertson *et al.* 2014). The potential for flushing containment fed ewes warrants further investigation given the large potential increases in lambs born observed in grazing studies.

4.1.3.3.8 Toxins in feeds

Urea may be fed to ewes in containment to increase dietary nitrogen when fed diets with inadequate protein, but is toxic if consumed at excess levels (SCA 1990). Feeding urea at rates of 3% (Bishonga *et al.* 2006) or 1.9% (McEvoy *et al.* 1997) of a hay/molasses diet caused embryo mortality and reduced pregnancy rates. There was some evidence that rates of 1.5% could be detrimental (Bishonga *et al.* 2006). The current recommendation that urea can be included at up to 2% of the diet (DEDJTR 2018) therefore appears a risk for ewes at joining. At least in cattle, high levels of protein supplementation are more likely to reduce embryo development if they occur in cows in negative energy balance, and the supplementation is acute (Velazquez 2011). This indicates that care should also be taken to ensure ewes are maintaining weight at joining if urea supplementation is used. In contrast, feeds of high true protein content, such as lupin grain, improve reproductive rates (Nottle *et al.* 1997b).

A range of toxins may be found in feeds which impair fertility or cause embryo mortality, and are reviewed elsewhere (McEvoy *et al.* 2001). These include fungal or bacterial toxins/products which may occur in feeds, as well as toxic plants, imbalances of nutrients in common feeds and chemical residues. Otherwise safe feeds may contribute to reduced fecundity. For example, coumestrol concentrations of 25 mg/kg in *Medicago* species (lucerne and annual medics) may reduce ovulation rate in ewes if fed prior to or during joining (Reed 2016). These high levels may occur in plants stressed by leaf disease or aphid attack, although coumestrol levels may be low in healthy plants. Therefore care needs to be taken to select quality, appropriate feeds particularly around the joining period.

4.1.3.3.9 Frequency of feeding

The current containment feeding guidelines recommend feeding on alternate days or less frequently (McFarland *et al.* 2006; Bell *et al.* 2016; DEDJTR 2018). This is based on studies with wethers (Franklin and Sutton 1952) and unmated ewes (Briggs *et al.* 1957) which have shown that daily feeding leads to more variable intake between sheep and higher rates of mortality than when sheep are fed at weekly intervals. Feeding once or three times weekly has resulted in similar rates of weight gain (Kahn *et al.* 2009).

Pen studies show there may be no impact of feeding frequency on reproductive rate. Barbarine ewes fed a hay/grain ration at 1.5 x maintenance requirement before and after mating produced similar fertility and fecundity when fed either daily or every second day (Khlil *et al.* 2017). Feeding pregnant ewes three times weekly from before joining and during pregnancy, rather than daily, has not reduced ewe weight gain, lambing percent, lamb birth weight or growth of lambs to 30 days (Jordan and Hanke 1963), although there were low numbers of ewes in this study.

Less frequent feeding reduces labour requirements for feeding. However, while sheep can be safely fed maintenance rations of high-grain diets at weekly intervals once adapted to the ration (Franklin and Sutton 1952), a reduced feeding frequency may increase the risk of acidosis (Kaufmann 1976; Krause and Oetzel 2006). Feeding cattle at weekly intervals, rather than daily, increases the risk of digestive disturbance when fed all-grain diets (Southcott and McClymont 1960). Ewes as well as rams need to be well-adapted to high-grain diets prior to joining to minimise any potential impacts on health, nutrition, or behaviour which may reduce reproductive rates.

4.1.3.3.10 Feeding methods

No literature has been found to indicate that there is an optimal method for feeding ewes. Feeding hay and grain in separate troughs has given similar growth rates of lambs as the same feedstuffs either pelleted or fed as a mixed ration (Bowen *et al.* 2006). Pelleting of diets prevents selection of components (Kirby and Beretta 2004), but the importance of this is not clear when ewes are fed at maintenance levels and given feed with few components. Industry reports indicate that a variety of feeding methods give satisfactory results, including trailing on the ground and use of feed troughs (Morbey and Ashton 1990). Self-feeders protect feed from weather. However, some self-feeders are designed for *ad libitum* feeding and may not readily allow accurate rationing of feed to maintenance levels. Observations by Ransom and the Elmore Field Days Sheep Committee (2020) suggest that self-feeders lead to greater variation in weight changes, with some ewes not accessing adequate feed, compared with trail feeding. Further studies are needed to clarify the management situations and level of response where this occurs.

Recommendation

- The current containment-feeding guidelines could be updated to correct information regarding condition score management of rams, and to highlight the risks of using small groups of rams, inadequate percentages or very short durations of joining.
- There is a lack of experimental reports regarding any impact of ewe mob size on reproductive performance, and any benefit of separation of different groups (breed, age, condition score) at joining.
- There is a lack of experimental reports comparing the effectiveness of various strategies for identifying and removing shy feeders.
- There is a lack of or conflicting experimental reports on optimal feeding strategies at joining and their impact on reproductive performance (lambs scanned or marked per ewe joined).

- The impact of condition score of ewes at joining on the number of lambs produced is well detailed in the current guidelines

4.1.3.4 Feeding strategies for pregnant ewes in containment areas

Optimal management of ewes throughout pregnancy is targeted at cost-efficiency, maintenance of health and fetus, and preparing the ewe and fetus for optimal survival and production after birth.

4.1.3.4.1 Level of feeding, placental growth and lamb birthweight

Most embryonic losses occur prior to day 30 after mating, and ewes may have the opportunity to re-mate, while fetal losses from day 60 to term range between 0 and 5.3% (Quinlivan *et al.* 1966; Jordan *et al.* 1989; Viñoles *et al.* 2012). Higher losses can occur with severe malnutrition, disease, and with multiple ovulations (Kelly *et al.* 1989). Maintenance levels of nutrition post-joining are therefore recommended. One exception is where ewes are in score 4+ fat condition so are at increased risk of metabolic issues such as pregnancy toxaemia during late pregnancy (Caldeira *et al.* 2007). Gradual loss of condition during early to mid-pregnancy in fat ewes may reduce the risk of pregnancy toxaemia during late pregnancy. The second situation where maintenance feeding post-mating is not recommended is for ewes at or below condition score 2.0, as these also are at increased metabolic risk (Caldeira *et al.* 2007), and any further loss of condition increases their risk of mortality (Doughty *et al.* 2019). Some gain in condition score for these ewes is desirable to reduce the risks in late pregnancy and at lambing.

Management of ewes during pregnancy is aimed at maintaining ewe health and fetal growth to optimise ewe and lamb survival around the lambing period. Lamb birthweight is associated with perinatal survival, with the optimum birthweight 3.6 to 5.5 kg, although varying with birth type and breed (Hatcher *et al.* 2009; Hinch and Brien 2014). Increases in birthweight above the optimal range are expected to increase mortality at birth due to dystocia, so optimal survival is achieved with average birthweights (Hatcher *et al.* 2009). Fetal growth and hence birthweight are associated with placental growth, as reviewed by Kelly and Newnham (1990). Placental size reaches a maximum at approximately day 80 of pregnancy. A maintenance level of nutrition during early and mid pregnancy supports placental growth, and sub-maintenance levels may result in lower birthweight lambs even if nutrition in late pregnancy is returned to maintenance levels. In contrast, the impact of moderate nutritional restriction on birthweight and postnatal growth during pregnancy may be small, and is reviewed elsewhere (Greenwood and Thompson 2007). Other studies show that improved nutrition during late pregnancy can prevent reductions in birthweight expected from mid-pregnancy restriction (Paganoni *et al.* 2014).

However, the response in placental growth to nutrition is influenced by the condition score of ewes. Robinson *et al*. (2002) concluded that sub-maintenance feeding to lose 0.5 condition score between day 30 and 90 of pregnancy increased placental and fetal growth for ewes in condition 3.5 at mating. However, for ewes in condition 2 at mating, nutritional restriction through mid-pregnancy reduced placental growth and lamb birthweight. When ewes were fed at maintenance levels, the body condition of the ewe at mating appeared to not determine placental or fetal growth rates, although lambs from ewes maintained at condition score 2.9 rather than 2 had 20% higher fat reserves at day 146 of pregnancy (McNeill *et al.* 1997). Higher fat reserves in lambs improve their potential for survival and are of increased importance for lambs born during cold weather (Alexander 1962).

4.1.3.4.2 Condition score management during pregnancy for lamb survival

Under paddock supplementary feeding conditions, feeding ewes in condition score 2.5 or more at lower levels which allow some condition score loss during pregnancy was shown to be more profitable than higher feeding levels, because neither birthweight nor lamb survival was reduced (Beetson 1986). While this may not have long-term consequences if ewes can regain weight prior to the next joining, continued loss below condition score 2 is not acceptable for sheep welfare. In contrast, other studies have shown that managing ewes to maintain a condition of 2.7 to 3 during late pregnancy, rather than consuming < 80% of energy requirement and losing condition, increased ewe survival by 16% and twin lamb survival by 29% (Edwards *et al.* 2011). Similarly, sub-maintenance feeding during the last 6 weeks of pregnancy to ewes of 40 kg liveweight (estimated to be < condition score 2), such that ewes only increased liveweight by 3%, has caused poor maternal behaviour post-lambing, and resulted in twin mortality rates of 33%, compared with 15% for ewes gaining 22% liveweight (Putu *et al.* 1988). The level of single lamb mortality was not reduced. These results are consistent with grazing studies using composite ewes, where a loss of ewe condition between mid-pregnancy and lambing is associated with a reduction in lamb survival (Behrendt *et al.* 2019). In Merino ewes, a loss of condition from 2.8 to 2.4 over mid to late pregnancy has reduced lamb survival compared with ewes which maintained condition (Hocking Edwards *et al.* 2019).

The effect of sub-maintenance feeding is distinct from that of condition score. Kenyon *et al*. (2012) showed Romney ewes maintaining condition score of approximately either 2 or 3 to 136 days after joining, then given *ad libitum* grazing, resulted in similar rates of lamb survival. Likewise, minimal differences in birthweight and lamb survival resulted from reducing ewe condition from 3 to 2 by day 100 of pregnancy, when ewes re-gained condition score during late pregnancy (Kenyon *et al.* 2011; Oldham *et al.* 2011). Given ewes require containment feeding due to low pasture availability, ewes in containment feeding systems may be in lower condition score than would normally be occurring at pasture. King (1990) suggested that acceptable levels of lamb survival were obtained when maintaining twin bearing ewes in condition ≥ 2.1 (80% survival), while singles could be maintained at condition 1.9 (90% survival). However, these ewes lambed in May when the risk of cold stress is low relative to winter lambing. Their suggestion differs from the current guidelines which indicate reductions in lamb survival for ewes maintained in score 2 or 2.5 during pregnancy, rather than the optimal 3.0 (DEDJTR 2018) and it is important to note the potential difference between intensively managed research sheep and large commercial flocks, and potential weather conditions at lambing. Where the average condition score of a mob is 2, there will be a proportion of sheep which are below score 2, and the risk of ewe mortality is increased for ewes less than condition score 2 (Doughty *et al.* 2019). Where the mob average is low, separation of low-condition ewes for preferential feeding is recommended to maintain ewe welfare standards, and this should be done before they fall below condition score 2.

Gain in condition score (above-maintenance feeding) during mid to late pregnancy may not increase lamb survival. Recent grazing studies (Hocking Edwards *et al.* 2019) indicate that gain in ewe condition from condition score 2.8 at day 50 of pregnancy to higher scores (up to 3.6) by lambing, did not appear to increase lamb survival (lambs marked per fetus scanned) from Border Leicester x Merino ewes. Similarly, a*d libitum* feeding between days 50 and 139 of pregnancy has not improved lamb survival from Romney ewes compared with those fed at maintenance (Kenyon *et al.* 2011). However, in Merino ewes, while the survival of single lambs was not increased if ewes maintained or gained condition, in multiple-bearing ewes, lamb survival was increased if ewes gained condition score from day 50 of pregnancy to be 3.0 at lambing, in comparison with ewes which only maintained condition score at 2.8 (Hocking Edwards *et al.* 2019).

Managing ewes to be more than condition score 3.5 at lambing is not recommended as fatter Romney ewes have weaned 22% less lambs, despite similar number of fetuses scanned (Tait *et al.* 2019). The cause was not identified but may have resulted from higher rates of dystocia. This is consistent with lower lamb survival for ewes which were in condition score 3 at joining but gained approximately half a condition score during late pregnancy (Behrendt *et al.* 2019).

Feeding ewes to gain condition during early and mid-pregnancy may have different effects in ewe lambs compared with adults. Feeding ewe lambs (5 months of age) to grow at 234 rather than 75 g per day from embryo transfer to day 95 of pregnancy reduced placental weight and birthweight of lambs, the difference being attributed to nutrient partitioning to maternal growth (Wallace *et al.* 1996). However, other studies have not found such an effect, although the weight of lambs produced was 1.8 kg heavier from rapidly growing ewes at day 68 of lactation (Kenyon *et al.* 2008). In contrast, feeding adult ewes 1.65 to 2.2 x maintenance requirement during pregnancy did not change placental or lamb birthweights (Wallace *et al.* 2005).

It is clear that maintenance levels of feeding need to be used particularly during late pregnancy to avoid reductions in perinatal lamb survival. Maintenance levels of feeding appear to be more important than ewe condition score, for ewes ≥ 2. Excess gain in ewe condition and loss of condition score should both be avoided during late pregnancy. Further studies are needed to clarify the production and financial consequences from controlled maintenance feeding at lower compared with moderate condition scores, as an increased proportion of ewes may be < condition score 3 in poor seasonal conditions. Unlike the grazing situation, in containment areas energy supply is easily calculated and there is a lower risk of unintended sub-maintenance nutrition during late pregnancy.

4.1.3.4.3 Feeding pregnant ewes for colostrum production

Adequate nutrition is required during pregnancy to ensure sufficient colostrum at birth for lamb survival. Lambs require 50 ml/ kg weight at birth (Robinson *et al.* 2002), and 280 ml/kg liveweight on the day of birth to meet their energy requirements if air temperatures are 0-10° C (Mellor and Cockburn 1986). Sub-maintenance feeding during late pregnancy may result in no colostrum being present at birth, and reduce both colostrum and subsequent milk production (McCance and Alexander 1959). The condition score of ewes may be important where energy intake is below requirement (Banchero 2003). In that study, single-bearing ewes grazed to achieve a condition score of 1.65 at day 143 of pregnancy have produced more colostrum that those at condition score 2.72, but in twin-bearing ewes, those in condition 1.68 vs 2.49 produced 75% less.

A low condition score *per se* does not prevent adequate colostrum production where ewes are fed at maintenance requirement. Banchero *et al*. (2006) maintained single-bearing Merino ewes at approximately condition score 2 during late pregnancy, and ewes produced 270 ml/kg birthweight in 18 hours, whereas those fed at 70% of requirement and in condition score of approximately 1.4 pre-lambing produced only 190 ml/kg birthweight. In contrast, an earlier study (Banchero *et al.* 2004) showed that single but not twin-bearing ewes would produce adequate colostrum on the day of birth when fed at maintenance requirements throughout pregnancy and maintained in a condition score of approximately 1.5. However, sub-optimal production was corrected by introduction to maize from 14 days before due lambing date, and feeding 750 g maize for 7 days before expected lambing. Colostrum production has also been increased by feeding 0.6 kg/ewe barley daily for 7 days prior to lambing (Banchero *et al.* 2007) or by grazing higher-energy pastures for 14 days prior to lambing (Banchero *et al.* 2009). For commercial grazing flocks where oestrus is unsynchronised, feeding lupin grain three times a week the equivalent of 500g/ewe per day for 2 weeks, from 1 week before the expected start of peak lambing, has increased lambs marked or weaned by 7% per ewe joined in ewes otherwise fed at maintenance levels (Nottle *et al.* 1998). Most of the colostrum from pre-lambing supplementation is accumulated during the 12 hours prior to parturition (Banchero *et al.* 2004), and lactogenesis is initiated 1 to 4 days before parturition (Hartmann *et al.* 1973) so it is unclear whether such an increase in nutritional level can be delayed to less than 7 days pre-lambing.

4.1.3.4.4 Feeding practices for pregnant ewes

As for joining, there is limited scientific literature evaluating optimum mob size or feeding practices for containment-fed ewes. Ewes may enter containment areas at any stage of pregnancy, and as for joining, where grain diets are fed, introduction to the ration is needed to avoid acidosis. Careful introduction to grain-based diets is needed particularly for late pregnant ewes to avoid depressions in intake which may trigger pregnancy toxaemia (Schlumbohm and Harmeyer 2008). Subclinical acidosis causes poor growth rates in lamb feedlots (Kirby and Beretta 2004), and the risk of acidosis may increase in late pregnancy due to the increased quantities of feed required for maintenance. Similarly, introduction to containment feeding is recommended to occur prior to late pregnancy, so that shy feeders may be identified and removed before they are at high risk of pregnancy toxaemia. Pregnant ewes may lose condition while in containment, which may be exacerbated under muddy conditions where feed is fouled (Hunter and Whale 2019), increasing the risk of pregnancy toxaemia.

Previous estimates indicate that 36% of Australian producers use transabdominal ultrasound for pregnancy status, and of those only 43% determine fetal number (Jones *et al.* 2011). Fetal number can be detected with an accuracy of 97% for ewes 45 to 100 days gestation (Fowler and Wilkins 1984). Improved ultrasound technology is now available (Barbagianni *et al.* 2017). Fetal age can also be determined (Bunter *et al.* 2018), which may facilitate separation of ewes for more precise feeding. Cost savings in feed will vary depending on the proportions of non-pregnant, single and multiple-bearing ewes, and duration of feeding. As shown in Table 2, maintenance requirements during late pregnancy are approximately double that of non-pregnant ewes. Pregnancy scanning to determine fetal number is advisable for ewes in containment areas to allow feeding to maintenance requirement to reduce feed costs while meeting liveweight/condition score targets. In addition, enabling singles and twins to be fed separately reduces competition and minimises the risk that twin or multiple-bearing ewes obtain sub-maintenance intake, reducing perinatal lamb survival. Likewise, the separate feeding of ewes with single foetuses minimises the risk that these ewes obtain excess feed, resulting in increased rates of dystocia and so also reducing lamb survival.

When fed to maintenance energy and protein requirement, there is no evidence that any particular common feedstuff is preferable for feeding pregnant ewes. However, while 100% wheat diets have maintained ewes during late pregnancy, lamb survival and growth has been poor when this diet continues into lactation (Watson and Egan 1985). While it has been recommended that the percentage of roughage in the diet is increased during late pregnancy (DEDJTR 2018), ewe intake is restricted in late pregnancy (SCA 1990). Increasing consumption of lower-energy roughage at the expense of grain will reduce energy intake and may reduce colostrum production and lamb energy reserves at birth.

However, no data has been found to indicate the optimal time at which roughage needs to increase during pregnancy. This is important since roughage is usually more expensive per unit of energy than grain. The duration of feeding additional roughage in late pregnancy may be short, since high-energy supplements introduced from two weeks prior to lambing have increased colostrum production and lamb survival (Banchero *et al.* 2009), with increased colostrum production even when ewes were in condition score 1.5 (Banchero *et al.* 2007). However, those studies supplemented grain to a roughage diet, so the response to increased roughage in a grain-based diet typical of containment feeding is unclear.

The optimal frequency of feeding ewes during very late pregnancy is also unclear. SCA (1990) cite studies where high concentrate diets when fed infrequently reduce milk fat in cows. However, as discussed above, the optimal time during late pregnancy at which daily feeding needs to be introduced is not defined. The current containment feeding guidelines (DEDJTR 2018) state that daily feeding is required by ewes during the last six weeks of pregnancy and lactation, with no reason provided. However, infrequent feeding may result in ewes consuming no feed on some days. A reduction in feed intake during the last three weeks of pregnancy, such as by a 15 hour fast, may trigger pregnancy toxaemia (hypoglycaemia), particularly in twin-bearing ewes, due to a reduction in glucose production by the ewe (Schlumbohm and Harmeyer 2008). To minimise this risk, daily feeding during at least the last three weeks of pregnancy appears to be warranted.

Where pregnant ewes are containment-fed during hot weather, strategies to reduce heat stress maybe necessary. Heat stress caused by exposure to temperatures of 40°C (9 hrs) and 30°C (15 hrs) at 40% relative humidity during mid to late pregnancy can reduce placental weight by 54%, reducing fetal weight (Bell *et al.* 1989) and therefore, potentially perinatal survival of lambs (van Wettere *et al.* 2019). Altering time of joining may reduce the risk of high temperatures during pregnancy. Provision of shade will also reduce heat stress.

Heat stress can cause changes in feeding behaviour to less frequent and larger meals which increases the risk of acidosis (Hyder *et al.* 2017). In a review, Sevi and Caroprese (2012) recommend changes to feeding management to improve the ability of sheep to cope with heat stress. They suggested feeding ewes in the late afternoon, rather than earlier, and with smaller but more frequent meals to reduce the heat production of sheep during the time of peak ambient temperature. However, other reports showed feeding in the afternoon or splitting feeds during the day, rather than feeding once in the morning, increased heat stress under warm conditions with high humidity (86% relative humidity) (Godfrey *et al.* 2013). The reduction in feed intake and increase in energy usage for thermoregulation in hot weather can be managed by feeding a high-energy diet, to maintain energy intake, while the increase in nitrogen catabolism may be managed by feeding protein sources with low rumen degradability (Sevi and Caroprese 2012). Very high doses of vitamin E (100 IU/kg DM) and selenium (1.2 mg/kg DM) have also reduced the impact of heat stress and allowed ewes to maintain feed intake (Chauhan *et al.* 2014), although the pre-treatment mineral status of the ewes was not reported. If effective, it is unclear whether such supplementation would be economically viable. Further research to evaluate the potential for dietary manipulation to minimise heat stress has been recommended (van Wettere *et al.* 2019), although a logical first step would be assessment of whether or not heat stress is reducing reproduction in ewes managed in shaded containment areas.

Recommendations

- The current guidelines clearly define the reduction in lamb survival associated with ewes losing condition score during late pregnancy, so no update is required.
- Investigation of the production and financial consequence of feeding to maintain condition at different levels regarding the impact on lamb survival. The literature provides conflicting guidelines.
- Investigation of the optimal roughage content during late pregnancy, and the time at which roughage proportion should be increased is needed.
- Investigation of the time pre-lambing when feeding needs to be daily, rather than less frequent.
- Investigation of the situations where increased nutrition in the last weeks of pregnancy is effective to increase colostrum production
- Investigate whether heat stress is reducing reproduction when shade is available, and identify the conditions where improved shade or alternative strategies may improve reproduction.

4.1.4 Health

4.1.4.1 Causes of mortality

The level of mortality during containment feeding for all classes of sheep has been reported as averaging 1.4% over 11.2 weeks (annual equivalent 6.5%) (Morbey and Ashton 1990), similar to the

1.8% for an earlier report (Ashton and Hannay 1984). Approximately 85% of producers reported a mortality rate of 0 to 3% in both surveys. However, 5 to 11% of producers reported mortalities of ≥ 4%, and up to 15%, demonstrating opportunity for improvement. Importantly, duration of containment feeding up to 25 weeks did not increase mortality, and a larger number of sheep fed tended to reduce mortality (Morbey and Ashton 1990). The key causes of mortality identified by producers are shown in Table 3.

Differences between the two surveys may indicate different classes of sheep, different conditions, or different producer perceptions. However, it is clear that the major causes, acidosis and pregnancy toxaemia, and several health issues, can all be reduced by preventive management. Key health issues in containment and lotfeeding areas and their management are detailed elsewhere (Besier *et al.* 2010; Dickson and Jolly 2011).

Table 3. Key causes of mortality for containment-fed sheep, as identified by producers

Cause	Number of farms Morbey and Ashton 1990	Number of farms Ashton and Hannay 1984
Grain poisoning	16	12
Pregnancy toxaemia	11	minor
Accidents	8	minor
Enterotoxaemia	7	3
Shy feeders/poor doers	5	5
Suffocation	5	minor
Flystrike or worms	4	4
Sand impaction	minor	5

Returning late pregnant ewes from containment areas back to paddock grazing has resulted in high mortality due to pregnancy toxaemia where paddock feed was insufficient (Morbey and Ashton 1990). In addition to low levels of pasture biomass, release of ewes may involve a sudden change in diet which increases the risk of enterotoxaemia (Lewis 2011). The current guidelines recommend feeding ewes prior to release (DEDJTR 2018). A level of continued supplementary feeding may also be required, along with pre-release vaccination against enterotoxaemia. Depending on the time of release, this vaccination may be the recommended pre-lambing vaccination.

4.1.4.2 Additives

Calcium and magnesium are the most probable mineral deficiencies associated with containment feeding of ewes. Containment diets based on grain or cereal hays are expected to be deficient in calcium, so supplementation with agricultural limestone is recommended at a rate of 1.5% (SCA 1990). This is below the current containment feeding guideline of 2% (DEDJTR 2018). Magnesium requirements increase during late pregnancy and lactation (SCA 1990). Causmag sprinkled onto feed will supply magnesium. Salt may be useful as a means of promoting calcium and magnesium intake, and magnesium absorption, with a loose lick of limestone, causmag and salt in the ratio 1:1:1 commonly used for late pregnant ewes. Sodium may be deficient in conserved forage of lucerne, millet, sorghum, and canola, and in cereal grain, but sodium may also be present in the water supply (SCA 1990). While responses to sodium have not been observed for ewes, supplementation with sodium for ewes fed wheat diets has increased lamb birthweights (Saville *et al.* 1975).

With prolonged feeding and lack of access to green pasture or green hay, vitamin A and E may become deficient in containment-fed ewes. Where ewes have not had access to such feeds for 2 to 3 months, supplementation is recommended (DEDJTR 2018). Vitamin E deficiency has the potential to reduce reproduction in ewes and rams (Liu *et al.* 2014). However, supplementation from mid to late pregnancy to increase vitamin E and selenium concentrations in ewes has not consistently altered ewe weight or increased lamb survival (Sterndale *et al.* 2018), although an increase in lamb survival has been reported in some studies (Kott *et al.* 1998). Supplementation to increase the vitamin D status of ewes in late pregnancy has not increased ewe weights or lamb survival (Lockwood *et al.* 2016).

Numerous additives are marketed to minimise the risk of acidosis (SCA 1990). However, the most effective strategy is slow introduction to grain, including for changes in type of grain and batch of grain, and an adequate level of roughage in the diet.

Recommendations

- The current guidelines provide detailed information. Adoption activities regarding health management, particularly acidosis and pregnancy toxaemia prevention, may be beneficial.

4.1.5 Conclusions

While detailed guidelines are available for managing sheep in containment areas, there is limited experimental evidence relating specifically to the husbandry of ewes which may influence their reproductive performance. Due to the lack of studies, it remains unclear whether practices associated with containment feeding are reducing reproductive performance on commercial properties, but the large variation reported indicates potential for improvement, so investigation is warranted. This review identified a number of practices where there appears to be a significant risk to pregnancy rates, number of lambs born per ewe joined, or for subsequent perinatal lamb survival. Some of these can be addressed by updating the guidelines to reflect more recent scientific evidence, while for others, further research is recommended to enable improvement of the current guidelines. Recommended research areas identified were:

- Defining the level of reproductive performance and causes of lower performance in containment
- Mob size at joining and during pregnancy
- Method of identifying and frequency of removing shy feeders
- Benefit of separating ewe breed and aged ewes at joining
- Feeding strategies at joining (type, level, flushing)
- Proportion roughage during late pregnancy, when to increase to promote lactation, hay vs straw
- Condition score in late pregnancy when maintenance fed - impact on milk and lamb survival
- Feeding for colostrum – when is it effective?
- Defining whether heat stress reduces reproduction in shaded containment areas, and if so, means to reduce heat stress

- Acidosis/health management – an ongoing problem (adoption activities)
- Managing late pregnant ewes to minimise pregnancy toxaemia (adoption activities)
- Ram husbandry (adoption activities)

4.2 Producer practices

4.2.1 Focus group

A focus group with industry representatives from NSW, VIC, SA, and WA and the research team was held online on 9 April 2020. The purpose of the focus group was to define industry practice regarding containment of ewes, and to assist in identifying and prioritising RD&A needs. The participants were:

Susan Robertson (CSU) project leader, producer
Michael Friend (CSU) research team
Bruce Allworth (CSU) research team, producer
John Piltz (NSW DPI) research team
Allan Gunn (CSU) veterinarian, reproductive specialist

Joe Gebbels (MLA project manager)

Jim Meckiff (NSW consultant)
Anthony Shepherd (NSW consultant/producer)
Tim Leeming (VIC consultant/producer)
Nathan Scott (VIC consultant)
Troy Fischer (SA producer)
Tim Watts (WA consultant/producer)
Hamish Dickson (NSW/SA consultant/producer) was also consulted post-forum due to availability.

4.2.2 Current industry practices for containment feeding ewes

4.2.2.1 Pen design

Various pen designs are used. Feeding from the laneway systems is used and considered to provide some benefits to efficiency but may not be suitable for large mob sizes. Excessively small pens are viewed as impractical, could be difficult for vehicle movement, could contribute to excess mud or fouling of feed, and may not be suitable for alternative purposes. Most containment areas are built to access existing shade.

4.2.2.2 Timing of containment feeding

Regional differences in the typical month of joining influence whether or not ewes are commonly joined whilst in containment areas. Joining while in containment does not appear to be common in Western or South Australia, although that may reflect the experiences or knowledge of those present. It is common in other states, with one consultant citing 93% of clients using containment, and 52% of clients would join ewes in containment. In some regions the use of containment areas over the late summer/autumn period is becoming routine practice even in non-drought years, as crop stubbles or pasture often provide sub-maintenance nutrition at this time. Ewes are often in containment during pregnancy, and this could include late pregnancy.

4.2.2.3 Perceptions of impact on reproduction

Industry experience indicated that when well-managed and ewes are in condition score ≥3, the reproductive performance of ewes containment fed during joining and/or pregnancy is usually 'good', although direct comparisons with paddock performance under similar nutritional conditions, or for particular practices, were unavailable. Containment feeding was observed to improve pregnancy and twinning rates if ewes were otherwise allowed to lose condition score when grazing inadequate paddocks, as it improved nutritional levels. The reduction in energy requirement due to less mobility in containment has also been observed.

However, a reduction in reproductive performance or welfare associated with containment feeding was reported to occur sometimes. This was thought to be associated with:

- disease (examples included listeria – containment site located on rotting pasture; camphylobacter in unvaccinated ewes – confined high-density space promoting transmission; toxoplasmosis; abortion storms from unknown cause) or toxins (in feed, such as phytoestrogens, chemical poisoning such as feeding on the site of an arsenic dip
- sudden changes in feed quality, such as from different batches of grain or roughage, possibly due to subclinical acidosis
- possibly heat stress due to lack of shade
- the use of lick feeders rather than trail feeding increasing shy feeders
- mixing different stock classes within a mob (eg ewe lambs and adult ewes)
- muddy pens leading to foot abscess in rams; rams not being introduced to feeding, or being too thin or too fat
- insufficient roughage
- mineral deficiencies
- failure to vaccinate for clostridial diseases (pulpy kidney) or drench
- poor introduction to feeding resulting in subclinical acidosis and pregnancy toxaemia
- sudden change in diet when released from containment leading to pulpy kidney or pregnancy toxaemia.

4.2.2.4 Ram management

Merino rams are often considered to be too thin and terminal type rams too fat at joining. Producers use a similar percentage of rams as they would for paddock joinings. Rams are commonly supplemented with lupins in the weeks pre-joining, but not in all locations due to rams often already being too fat, which may reflect differences in the breeds and month of joining as well. Rams are not always adequately adapted to the environment (young purchased rams) or introduced to the containment ration. The percentage of rams used varies, with recommendations of 1.5 to 3%, although most producers probably use 1.5 to 2%. The duration of joining varied, but was sometimes longer than the maximum 5-6 weeks suggested. Some consultants recommend teasing to reduce the length of joining required.

4.2.2.5 Feeding management

Producers typically feed less frequently than daily due to the reduction in labour required, although feeding daily may occur in late pregnancy as the quantity of feed required increases. The feeding frequency is somewhat limited by the size of the equipment, so quantity of feed per load or bin. A variety of feeding methods are used, including trail feeding on the ground, use of belting/trough systems, and lick feeders. The optimal method is unknown, however, forum participants noted the high cost of equipment for systems other than trail feeding, particularly if a large number of ewes is being fed. There was also a strong perception that lick feeders increased variability in intake and contributed to an increased incidence of shy feeders. The percentage of shy feeders in ewe mobs isn't clear, and whether they occur at an important level is unknown. However, an average of 5%, with range < 1 to 20% has been reported.

A wide range of feed types are used. Cereal grains with either hay or straw are common. The proportion of roughage tends to be increased with better quality hays. Most producers tend to feed roughage *ad libitum* so some is always available. Some producers have fed grain-only rations, and high mortality rates have sometimes occurred with this practice. A wide range of feed additives are being promoted and used which may be unnecessary.

Reports suggested that ewes were often allowed to fall in body condition prior to entering containment. The level of monitoring of condition score whilst in containment may not always be frequent enough to allow alteration of nutrition to prevent loss of weight loss. Feeding difficulties may be increased with larger mob sizes. A wide range in mob sizes are used. Although some consultants are reluctant to advise the use of mob sizes >400, some producers regularly feed >1000 ewes successfully.

4.3 Research, Development and Adoption Priorities

4.3.1 Research priorities

Research gaps identified both from the literature review, during or after the forum are listed in Table 4. Those identified during the forum were prioritised then to record industry views, although priorities did vary between participants. After assessment of the potential industry impact, ease and cost for producers to implement, risk that each factor would reduce reproductive performance and health, and ease of conducting a research project (shown in Appendix 9.3), the final priority rankings were given as shown. Those topics which were not priorities at the forum, or which were identified as having a low impact, have not been given a priority rank.

Table 4. Research topics identified and priority ranking to improve reproductive performance and health

Research Gaps	Forum Priority	Final Rank
Optimum level of roughage	high	1
What is the maximum safe quantity of feed in one feed? (risk subclinical acidosis)	medium	2
Optimum mob size – impact on reproduction and shy feeders	high	3
Shade – impact on reproduction	high	4
Optimum feeding method (lick feeders, trail, trough)	low	5
Condition score and feeding in late pregnancy for lamb survival		6
How to manage shy feeders, and what practices increase the incidence	high	7
Impact of separation of breed/flock structure (eg age, CS group)	low	8
Is vitamin ADE and selenium supplementation in mature ewes beneficial	low	
Water trough length and flow rate - adaptation to short length	low	
Causes of high worm burdens, pregnancy toxaemia, other health issues		
Impact of ram percentage on pregnancy rate/fecundity		
Impact on conception of handling/feeding ewes during joining and up to 4 weeks post-joining		

4.3.2 Development and adoption priorities

Adoption topics were not prioritised at the forum due to limitations in time. The topics identified are shown in Table 5. These topics were given a priority ranking based on impact to industry in terms of reproduction, ease for a producer to implement, cost for a producer to implement and risk to industry, as shown in Appendix 9.3.

Table 5. Adoption gaps identified and priority ranking to improve reproductive performance and health

Adoption Gaps	Rank
Ram management/introduction of rams to feed/ram percentage/joining duration	1
Introduction to feed	2
Genetics/feedtests vary – need to monitor ewes, and frequency of monitoring	3
How to manage ewes when removing from containment	4
Do not mix stock classes/need for single/twin/triplet separation (shy feeders/feed requirements differ), and benefits of separating condition score groups	5
Need for health treatments (drench, vaccinate, calcium/magnesium), no need for unnecessary additives	6
Need to monitor water quality	7
Site selection (toxic, shade etc), durability of facilities, design for other purposes/practicalities	8

5 Discussion

5.1 Completion of project objectives

5.1.1 Completed a literature review on the management of reproductive performance and optimised feed strategies for pregnant ewes in containment areas. A focus group to gather feedback from producers will also be undertaken.

A literature review has been completed. Unfortunately, very few scientific papers have been published which evaluate practices used in containment management of large mobs of breeding ewes. While principles, where relevant, have been extrapolated from pen-feeding studies, pen studies often use types of feed or feeding practices which are not commonly commercially used.

Sheep behaviours may also differ between the relatively small group sizes in experiments, and the large sizes used commercially. The lack of valid comparative data, and the known large variation between years and properties in reproductive performance mean that it is not currently possible to determine whether containment feeding practices may be improved. Small reductions in lamb marking rates are unlikely to be recognised, yet reduce profitability. Hence, there is a need for further research to clarify any impact of key husbandry and feeding practices on reproduction from containment ewes at differing stages of the reproductive cycle (joining, pregnant, late pregnant, lambing) so that optimum practices can be identified. The project leader is currently undertaking a national survey of producer practices and reproductive performance associated with containment and supplementary feeding of ewes, which will provide current benchmarks.

A focus group with national industry representatives was held on 9 April 2020. Videoconferencing was an effective and cost-effective means for conducting an industry forum, although with more participants it may be less desirable. Industry input provided essential information on current producer practices, and perception on research and adoption priorities. It is acknowledged that the perceptions reported may be biased by the experience of those contributing.

5.1.2 Complete a draft journal article based on the literature review.

A journal article has been submitted. In addition, a conference paper has also been submitted for the Australian Association of Animal Sciences conference. If accepted, these will raise awareness of some of the issues associated with containment management.

5.1.3 Developed (in consultation with the MLA Adoption and Communications teams) and provided to MLA extension materials reflecting guidelines for producers to optimise the feeding and management of breeding ewes in containment areas.

A draft two-page fact sheet, powerpoint presentation, guidelines (see Appendix 9.4) and three producer case studies (Appendix 9.5) have been sent to MLA for development into extension materials. These add to the large number of guidelines for containment feeding currently available. However, the previous guidelines have included conflicting advice, advice which is contradicted by scientific studies, and advice which is based on opinion, not data. The reliance on scientific evidence to develop the updated guidelines means that MLA and producers can have increased confidence that they are sound.

5.1.4 Completed and provide to MLA a final report documenting the relevant literature, current practices, researchable gaps, and a prioritised list of potential R&D or A activities for managing the reproductive performance and feeding of ewes in containment areas.

A final report has been completed, although submitted late due to delays in the contracting process.

5.1.5 Delivered the findings of this project to the Graham Centre Livestock Forum, through media activities, and publish the findings on at least one producer-accessible

website, including 3 producer case studies. Note this objective will not be complete until 31st July 2020.

A project presentation has been booked into the Graham Centre Forum to be held on 31 July, and is being publicised through advertisements for that event. A project description, including key guidelines and three case studies, will be uploaded onto the Graham Centre website when permission from MLA is obtained. These activities all provide national exposure to producers and other relevant sheep industry participants.

6 Conclusions/recommendations

There is a lack of evidence quantifying the impact of containment management of breeding ewes on reproduction and health. It remains unclear whether reproductive rates are altered by containment practices, although it is clear that acidosis and pregnancy toxaemia are a common concern. It is evident that reproductive rates are highly variable, and so could be improved. Further research to quantify any impact of key practices on reproductive rate, and adoption activities to assist producers to make informed choices, are recommended. These activities would minimise the risk of reduced production, may improve lamb marking rates, reduce the risk of high mortality rates, and demonstrate industry commitment to improving the health and welfare of breeding ewes.

7 Key messages

The key guidelines and messages resulting from this project are:

MLA has produced updated guidelines for producers to optimise the health and reproductive rates from ewes managed in containment areas.

Optimal mob size, space allowance and design is unknown. Ensure adequate shade, water and access to feed, and safety. Minimum 1.4 m^2/ewe for heavy sheep, 1.8 m^2/ewe for ewes with lambs to meet welfare requirements.

Minimise potential health issues by vaccination for pulpy kidney and other clostridial diseases, monitor faecal egg counts and drench if needed, and addition of 1.5% limestone to grain or cereals. Seek veterinary advice if needed.

Slow introduction of grain to ewes and rams is key to preventing acidosis, and a minimum 10% roughage is needed.

Monitor ewes regularly to make sure feed is adequate, and remove shy feeders promptly to maintain health.

Feeding at less than daily intervals, and feeding straw rather than hay as roughage, reduces the level of shy feeders.

Reduce the risk of low lamb marking rates by maintaining adequate condition score of ewes and rams (minimum 2.0, but better results may be obtained with higher score).

Manage rams for 2 months prior to joining to increase fertility. Increase nutrition to increase sperm production, target condition score 3 at joining, allow adequate exercise and prevent health issues.

Ram percentages of 1% for adult ewes, 2% for maidens, but if short joinings, or other risk factors (lower condition, heat stress), more rams may improve results.

Feed to avoid loss in ewe condition score in the last weeks of pregnancy to increase lamb survival after birth. Excess gain in condition may result in lambing difficulty.

Further research is needed to identify the best feeding practices for breeding ewes in containment. Updated guidelines will be made available when possible.

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9 Appendix

9.1 Scientific paper

The following manuscript was submitted to an international journal on 12 May 2020 for consideration for publication.

Review: Feed management of ewes to optimise reproductive rate when being containment fed

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Short title: containment feeding ewes

Abstract
Sheep which are normally managed under extensive grazing may be fed in containment areas when pasture is inadequate. Reproductive rates vary widely for ewes managed in containment areas, with pregnancy rates <50 to 96%. Historical Australian producer surveys indicate a possible ≥ 9% reduction in lambs marked per ewe joined on 20% of properties for containment-fed compared with paddock-managed ewes. However, direct comparison is difficult and it is unclear whether management practices used in containment are a risk to pregnancy or lamb marking rates. This review investigated feeding strategies for containment-fed ewes at joining and during pregnancy with the aim of identifying optimal management to improve reproductive rates. There is a scarcity of information concerning the level of reproduction and the timing and causes of low pregnancy or lamb marking rates, optimal mob size, methods for identifying shy feeders, benefits of mob separation, optimal feeding strategies at joining and during very late pregnancy. Pregnancy rates may be improved by pre-joining management to ensure all ewes reach a minimum condition score of 2 at joining. Further studies to define current producer practices would be useful in identifying interventions to improve reproductive rates.

Implications
This review has identified the lack of knowledge of optimal husbandry and feeding practices for ewes managed in containment areas. If further research can identify what practices are optimal, and producers not currently using these practices choose to alter their management, the pregnancy or lamb marking rates for containment-fed ewes may be improved, and the risk of low production reduced.

Additional keywords: sheep, nutrition, management, fertility, condition

Introduction

In Australia and other regions prone to periods of low rainfall and inadequate pasture supply, sheep may be fed in containment areas (drought lots) as a strategy to protect pastures and minimise soil erosion. Such areas can be either group pens or small paddocks, where sheep are fed their entire feed requirements. The principle objective of containment feeding is the maintenance of particularly breeding ewes, but also other classes of sheep, which would otherwise need to be sold, rather than targeted weight gain for production and slaughter (Morbey and Ashton, 1990). However, low reproductive performance, poor health and high mortality rates need to be avoided to maintain both longer-term profits and sheep welfare.

Current guidelines for managing sheep in containment areas are available (DEDJTR, 2018). However, some of the recommendations are based on anecdotal, rather than scientific evidence, so it is not clear whether the practices are optimal. Few studies have been found which evaluate the impact of particular containment management practices on reproductive performance, although there is anecdotal evidence that containment feeding sometimes reduces performance (Ashton and Hannay, 1984; Morbey and Ashton, 1990; Robertson and Friend, 2019). Identification of particular practices that contribute to low reproductive performance, and beneficial management intervention strategies, should reduce the risk of lower reproductive rates. The purpose of this review was to identify management of confinement fed ewes to optimise their reproductive performance. The focus was on joining and pregnancy, and excluded consideration of ewes lambing in confinement areas. Key factors considered included husbandry, nutrition, feeding strategies and ewe condition score.

Is reproductive performance of containment fed ewes suboptimal?

There is limited information in the literature defining the reproductive performance of containment-fed ewes under commercial conditions in Australia. Anecdotal reports indicate a range in pregnancy rates <50% to 96%. Where nutritional levels are higher than in paddock conditions, containment feeding could be expected to result in higher rates of pregnancy and fecundity. However, despite this, case reports indicate containment-fed ewes have produced 6 to 21% fewer lambs marked/ewe (lambs present at the end of the lambing period, when lambs are vaccinated, eartagged, and castrated), in comparison to ewes which were maintained in paddocks on the same properties (Ashton and Hannay, 1984; Morbey and Ashton, 1990). A survey of producers who containment fed pregnant ewes on the Australian Eyre Peninsula during 1988 found that while on average the lamb marking percentages (79%) were similar to the regional average in 1984, 18.9% recorded less than 70%, and 3.8% recorded less than 55% (Morbey and Ashton, 1990). It is not known what proportion of those farms joined ewes while in containment, the timing of any reproductive wastage cannot be determined, and comparison with a different year may overestimate any effect of containment feeding. However, these studies indicate that containment feeding is associated with reduced lamb marking rates on some properties, may be associated with ≥ 9% lower lamb marking rates on over 20% of properties, and certainly indicate suboptimal lamb marking rates have been common. Direct comparisons for containment and paddock feeding under similar nutritional conditions were not made, therefore it is not possible to determine whether specific nutritional or other husbandry effects were causative.

Management of ewes at joining

Joining - mob size and structure

Mob size has the potential to affect reproductive outcomes either through changes in mating or feeding behaviours. However, there is no scientific data determining the optimum mob size to join containment fed ewes. A wide range of mob sizes is used commercially, and pen mobs of > 500 sheep have been common on commercial properties (Ashton and Hannay, 1984).

The structure of mobs within pens may also be important. The return to service rate for maiden ewes increases as the percentage of mature ewes in the mob increases, so ideally maiden ewes should be joined in a separate mob (Restall, 1976). As they are expected to have lower liveweights than adult ewes, total feed requirements may be reduced by feeding maidens in separate pens. Arnold and Maller (1974) found that one year old and seven year old wethers were less competitive at feed troughs than intermediate ages, and that Merino sheep were less competitive than other breeds. These results indicate that it may be advisable to separate different breeds and some age groups when confinement feeding ewes, although there is no experimental evidence proving an adverse effect on reproductive performance.

Joining - ewe liveweight or condition score
Ewe condition score (1 = very poor, 5 = obese) (Jefferies, 1961) is an indicator of long-term nutrition. In extensive systems, the risk of ewe mortality is increased for individual ewes in body condition < 2 (Doughty *et al.*, 2019). For welfare reasons, ewes should be managed to avoid such low condition. Understanding the reproductive response requires defining where production is altered.

The liveweight or body condition of ewes at the time of joining influences both ewe fertility (ewes pregnant of those joined) and the number of ovulations, so fecundity (number of fetuses per pregnant ewes). Pregnancy rates decline rapidly when ewe liveweight falls below a threshold of approximately 40 kg in Corriedale, Romney and Merino ewes (Coop, 1962; Killeen, 1967; Cumming, 1977). The critical weight will vary with frame size. Above this weight the rate of non-pregnant ewes is relatively static at 4-8% (Coop, 1962). Data from Romney and Composite ewes show no increase in pregnancy rates when ewes were above a condition score of 1.5 (Kenyon *et al.*, 2004). Mating ewe lambs may require higher minimum condition targets. Romney composite ewe lambs in condition score 1.5 were less likely to be mated than lambs in condition ≥ 2, and 7% more lambs in condition 2.5+ became pregnant than those in condition 2 (Kenyon *et al.*, 2010). Maximum pregnancy rates in non-Merino ewe lambs have been reported at a condition score of 3.5 (Corner-Thomas *et al.*, 2015).

In addition to pregnancy rate, the number of lambs produced also depends on fetal number per ewe. Ovulation rates in Merino and Border Leicester x Merino ewes increase up to at least an estimated condition score 3, although possibly not above score 3 in some strains of Merino (Cumming, 1977). Twinning did not increase further for Romney ewes above condition score 3, or for composite ewes above condition 2, indicating no advantage to reproductive rate in maintaining ewes at higher condition scores (Kenyon *et al.*, 2004). The number of lambs scanned per ewe may also be reduced for Romney ewes ≥ 4.5, so that mating in high condition need not result in more lambs weaned per ewe (Tait *et al.*, 2019). However, other reports indicate an increase in the number of lambs born per mature ewe joined from condition score 3 (1.11), 3.5 (1.26) to 4 (1.38), for Merino and other breeds (Gonzalez *et al.*, 1997). This is consistent with a linear increase in the number of fetuses scanned per ewe joined of 1.7 to 2.4 additional fetuses per 100 ewes for each 1 kg increase in ewe liveweight at joining for Merino ewes with liveweights 35 to 65 kg (Ferguson *et al.*, 2011). The variation between reports indicate there may be a variation in reproductive response between breeds and strain.

The optimal condition score may also be lower for adult ewes than for those joined as lambs. For non-Merino ewe lambs, maximal numbers of fetuses per ewe joined have been achieved at a condition score of 3 (Corner-Thomas *et al.*, 2015). Kenyon *et al*. (2014) conclude that the relationship between condition score and reproduction is curvilinear, and with a decline in production in some breeds at high condition scores. They recommend separation of ewes to more efficiently feed those below a minimum condition score, rather than the whole mob.

The nutrition of ewes six months before mating may also influence ovulation rate. Nottle (1997) showed that ewes which lost 10 to 20% of liveweight six months before ovulation, but had regained their initial weight, had a lower ovulation rate (1.06) than ewes maintaining weight (1.28). Both groups produced 1.6 ovulations/ewe if flushed with lupin grain premating. These data indicate the need to manage ewe nutrition well in advance of, as well as during joining, to optimise reproductive performance.

Joining - feeding management

An additional consideration with containment feeding is shy feeders. Shy feeders are sheep which do not adapt to hand-feeding, and either don't eat, or don't eat adequately. Shy feeders occur at a rate of 5-7% even with small mob sizes (40 ewes/pen) (Kennedy and Bettenay, 1950). Rates as high as 18% have been reported for Merino lambs with 40 lambs/pen, and a lower initial liveweight does not distinguish these lambs (Rice *et al.*, 2016). The current recommendation (DEDJTR, 2018) is that the rate of shy feeders increases when the sheep are in mobs of over 400 sheep per pen. However no data exists on the link between mob size, shy feeders and reproductive rate.

The proportion of ewes that do not adapt to confinement feeding, particularly of grain, will lose weight. Removing and managing these shy feeders is critical to avoid deaths. However, there is little evidence defining the optimum means or frequency of identifying shy feeders. This is particularly important where large mob sizes are used, and ewes visually identified in feeding pens need to be re-identified when the mob is yarded for their removal. In addition, weighing and condition scoring all ewes is relatively time-consuming, creating practical impediments, so more efficient strategies are desirable.

Exposure of lambs to supplementary feeds while with their mothers (imprint feeding) improves intake of that supplement even 34 months later (Green *et al.*, 1984). Therefore, imprint feeding of lambs is recommended to increase the rate of adaptation to containment feeding as adults. Furthermore, it is advisable to avoid joining ewes during the period of adaptation to feeding, when some ewes may be losing weight, as reductions in feed intake over short periods can alter ovulation rate (Stewart and Oldham, 1986) and sub-maintenance intake potentially reduces embryo survival (Abecia *et al.*, 2015).

Joining - type of feed

Lupin grain can be safely fed to sheep without roughage, as it has a lower risk of causing acidosis than other grains (SCA, 1990), although some introduction to high levels will still be required. Rations varying widely in roughage content may be suitable if minimum protein and energy intake needs of the sheep are met. Proportions of wheat chaff in wheat grain diets of 10 to 50% are adequate for maintenance feeding of wethers (Franklin and Sutton, 1952). However, 20% roughage in the diet has been suggested as the optimum proportion (SCA, 1990). Rations comprising a small proportion of roughage (such as 10%) are also consumed more quickly (Sari *et al.*, 2018), increasing competition for feeder space (Clements *et al.*, 1979), but feeding the same total quantity but at less than daily intervals allows all sheep to access sufficient feed (Franklin and Sutton, 1952). Feeding straw rather than hay reduces the number of poor doers (shy feeders) (Morbey and Ashton, 1990).

There is limited evidence that any particular type of feed at joining results in better reproductive performance. When grazing abundant senescent pasture, supplementation with 0.5 kg/ewe/day lupins has produced more lambs born per ewe joined than ewes supplemented with the same quantity of either wheat or cut lucerne pasture (Kenney *et al.*, 1980). However, in superovulated heifers, the number of viable embryos was reduced by feeding a diet based on barley grain compared with citrus/beet pulp (Yaakub *et al.*, 1999), suggesting high grain diets may reduce pregnancy rates or fecundity. In contrast, ewes pen-fed pea silage or a ration of pea silage (20%), cottonseed meal (8%) and oat grain (70%) at similar energy and protein contents, have produced a similar pregnancy rate (90%) and number of lambs born per ewe lambing (1.26) (Gulliver *et al.*, 2013). Further investigation of any impact of type of feed at joining on reproductive performance is warranted.

No reports in the literature have been found to indicate that there is an optimal method for feeding ewes, although anecdotal reports suggest trail feeding reduces the proportion of shy feeders compared with the use of lick feeders. Feeding hay and grain in separate troughs has given similar growth rates of lambs as the same feedstuffs either pelleted or fed as a mixed ration (Bowen *et al.*, 2006), indicating simple feeding systems are adequate.

Joining -level of feed

The minimum energy and protein requirements vary with stage of gestation, and with frame size and the liveweight of ewes. The minimum crude protein requirement for adult sheep prior to late pregnancy is approximately 7%, with requirements increasing to around 12% during late pregnancy (SCA, 1990). While these estimates can be used as a guide, ewe condition should be monitored regularly for ewes in containment areas to ensure that they are being fed adequately.

Maintenance feeding is recommended at joining for containment-fed ewes. Feeding well below maintenance (0.5 maintenance) causes embryo mortality (Abecia *et al.*, 2015), and feeding at this level is not appropriate. In pen studies, twice maintenance energy levels of feeding may also reduce embryo survival and have reduced pregnancy rates by 20% (Parr *et al.*, 1987). That study used a 50% lucerne hay 50% barley diet. In contrast, feeding a grass-based pellet at twice maintenance has not reduced pregnancy rates (Muñoz *et al.*, 2008). Similarly, feeding 1.4 X maintenance energy levels of either silage or an oat-based diet has resulted in high pregnancy rates (≥ 90%) after a natural mating (Gulliver *et al.*, 2013). The reasons for the different response between studies is unclear, but may relate to type of feed.

In a study where groups were not replicated, ewes in containment areas where the quantity of wheat was increased from maintenance at 500g/ewe/day to 700 g/ewe per day during the second week of joining had a pregnancy rate of 57%, compared with 79% in ewes fed at 500 g/day during early joining (Robertson and Friend, 2019). Although this feeding level was not high, it is possible the type of grain contributed to the poor result compared with earlier studies, although subclinical acidosis was not observed. The reasons for the variation between studies is unclear, but warrants investigation due to the high impact on reproductive performance. Therefore, feeding above maintenance levels during joining is not recommended for containment-fed ewes until further studies show an increase in the number of lambs born.

There is minimal information on short-term flushing (increasing feed or energy fed prior to joining) of ewes to improve reproductive rates when containment fed. Short-term flushing targeting days 10-14 of the oestrous cycle (Stewart and Oldham, 1986) can be used in naturally cycling grazing flocks by increasing nutrition for 7 days before and during the first 7 days of joining (Robertson *et al.*, 2014). In that study, up to 21 additional fetuses per 100 ewes joined were produced by grazing higher-quality pasture. Longer-term grazing (9 weeks) has increased lambs born by up to 32% (Killeen, 1967). Therefore, short and longer-term increases in nutrition at joining for naturally cycling grazing ewes clearly can improve the number of lambs born. A response can be obtained for ewes in low condition (<2) (Killeen, 1967) as well as those in optimal condition (3.2) (Robertson *et al.*, 2014).

Various feeds have been assessed for flushing responses, and increase in the ovulatory response is due to an increase in glucose supply and hormonal changes (Vinoles *et al.*, 2005). Lupin grain has traditionally been used for flushing, but it seems that wheat grain is ineffective (Kenney *et al.*, 1980).

The potential for short-term flushing of containment fed ewes warrants further investigation given the large potential increases in lambs born as observed in grazing studies, but the variable impacts of high feeding levels in pen studies. Information is limited because most relevant pen-feeding studies only report ovulation rate.

Joining -toxins in feeds
Urea may be fed to ewes in containment areas when fed diets with inadequate protein, but is toxic if consumed at excess levels (SCA, 1990). Feeding urea at rates of 3% (Bishonga *et al.*, 2006) of a hay/molasses diet has caused embryo mortality and reduced pregnancy rates. There was some evidence that rates of 1.5% could be detrimental to reproductive performance. A range of toxins may be found in feeds which impair fertility or cause embryo mortality, and are reviewed elsewhere (McEvoy *et al.*, 2001). These include fungal or bacterial toxins/products, as well as toxic plants, imbalances of nutrients and chemical residues. Therefore, care needs to be taken to select quality, appropriate feeds particularly around the joining period.

Management of pregnant ewes in containment
Pregnant ewes - level of feeding and condition score management
Optimal management of ewes throughout pregnancy is targeted at cost-efficiency, maintenance of health and the fetus, and preparing the ewe and fetus for optimal survival and production after birth. Most embryonic losses occur prior to day 30 after mating, and ewes may have the opportunity to re-mate, while fetal losses from day 60 to term are usually low (Viñoles *et al.*, 2012). Inadequate nutrition has increased losses (Abecia *et al.*, 2015), so maintenance levels of nutrition post-joining are therefore recommended. One exception is where ewes are in score 4+ fat condition so are at an increased risk of metabolic problems such as pregnancy toxaemia during late pregnancy (Caldeira *et al.*, 2007). Gradual loss of condition during early to mid-pregnancy in fat ewes may reduce the risk of pregnancy toxaemia during late pregnancy. The second situation where maintenance feeding post-mating is not recommended is for ewes at or below condition score 2.0, as these also are at increased metabolic risk (Caldeira *et al.*, 2007), and any further loss of condition increases their risk of mortality (Doughty *et al.*, 2019). Some condition gain for these ewes is desirable to reduce risks in late pregnancy and at lambing.

Grazing studies have shown that managing ewes to maintain a condition of 2.7 to 3 during late pregnancy, rather than consuming < 80% of energy requirement and losing condition, increased ewe survival by 16% and twin lamb survival by 29% (Edwards *et al.*, 2011). Similarly, a loss of ewe condition score between mid-pregnancy and lambing has reduced lamb survival in composite (Behrendt *et al.*, 2019) and Merino ewes (Hocking Edwards *et al.*, 2019) compared with ewes which maintained condition, despite condition not falling below score 2.4. It is clear that maintenance levels of feeding need to be used during late pregnancy to avoid reductions in perinatal lamb survival.

Above maintenance feeding during mid to late pregnancy may not increase lamb survival. Gain in ewe condition from condition score 2.8 at day 50 of pregnancy to higher scores (up to 3.6) by lambing, did not appear to increase lamb survival (lambs marked per fetus scanned) from Border Leicester x Merino ewes (Hocking Edwards *et al.*, 2019). Similarly, a*d libitum* feeding between days 50 and 139 of pregnancy has not improved lamb survival compared with those from ewes fed at maintenance (Kenyon *et al.*, 2011). However, in Merino ewes, while the survival of single lambs was not increased if ewes maintained or gained condition, in multiple-bearing ewes, lamb survival was increased if ewes gained condition score from day 50 of pregnancy to be 3.0 at lambing, in comparison with ewes which only maintained condition score at 2.8 (Hocking Edwards *et al.*, 2019).

When ewes are fed at maintenance levels for the stage of gestation, the body condition of the ewe at mating does not appear to determine placental or fetal growth rates, although lambs from ewes maintained at condition score 2.9 rather than 2 had 20% higher fat reserves at day 146 of pregnancy (McNeill *et al.*, 1997). Higher fat reserves in new-born lambs may improve their survival. However, managing ewes to be more than condition 3.5 at lambing is not recommended as Romney ewes in higher condition have weaned 22% fewer lambs, despite similar number of fetuses scanned (Tait *et al.*, 2019). The cause was not identified but may have resulted from higher rates of dystocia. This is consistent with lower lamb survival for ewes which were in condition score 3 at joining but gained approximately half a condition score during late pregnancy (Behrendt *et al.*, 2019). Maintenance of moderate condition throughout pregnancy is therefore optimal for lamb survival.

Feeding pregnant ewes for colostrum production

Adequate nutrition is required during pregnancy to ensure sufficient colostrum immediately after birth for lamb survival. The condition score of ewes may be important where energy intake is below requirement, with twin-bearing ewes in condition 1.68 producing 75% less colostrum than those in condition 2.49 (Banchero, 2003). However, a low condition *per se* does not prevent adequate colostrum production where ewes are fed at maintenance requirements. Banchero *et al*. (2006) maintained single-bearing Merino ewes at approximately condition score 2 during late pregnancy, and ewes produced 270 ml/kg birthweight colostrum in 18 hours. In an earlier study (Banchero *et al.*, 2004) twin-bearing ewes fed to maintenance in condition 1.5 did not produce adequate colostrum, but production was corrected by feeding 750 g maize for 7 days before expected lambing. It is unclear whether such an increase in nutritional level can be delayed to less than 7 days pre-lambing.

Feeding practices for pregnant ewes

As for joining, there is limited scientific literature evaluating optimum mob size or feeding practices for containment-fed ewes during pregnancy. Careful introduction to grain-based diets is needed particularly for late pregnant ewes, since a reduction in feed intake may trigger pregnancy toxaemia (Schlumbohm and Harmeyer, 2008). Introduction to containment feeding is recommended to occur prior to late pregnancy to reduce this risk.

When fed to maintenance energy and protein requirement, there is no evidence that any particular common feedstuff is preferable for feeding pregnant ewes. However, while 100% wheat diets have maintained ewes during late pregnancy, lamb survival and growth has been poor (Watson and Egan, 1985). Ewe intake is restricted in late pregnancy (SCA, 1990), so increasing consumption of low-energy roughage at the expense of grain will reduce overall energy intake. No data has been found to indicate the optimal time at which roughage needs to increase during pregnancy. The duration of feeding additional roughage in late pregnancy may be short, since high-energy supplements introduced from two weeks prior to lambing have increased colostrum production and lamb survival (Banchero *et al.*, 2009). However, those studies supplemented grain to a roughage diet, so the response to increased roughage in a grain-based diet typical of containment feeding is unclear. There is not a consistent benefit from chopped compared with unchopped silage, nor from mixing concentrate and silage compared with feeding separately to pregnant ewes (Helander *et al.*, 2014).

The optimum frequency of feeding ewes during very late pregnancy is also unclear. SCA (1990) cite studies where high concentrate diets when fed infrequently reduce milk fat in cows. However, the optimal time during late pregnancy at which daily feeding needs to be introduced is not defined. The current containment feeding guidelines (DEDJTR, 2018) state that daily feeding is required by ewes during the last six weeks of pregnancy and lactation. A reduction in feed intake during the last three weeks of pregnancy, such as by a 15 hour fast, may trigger pregnancy toxaemia (ketosis), particularly in twin-bearing ewes, due to a reduction in glucose production by the ewe (Schlumbohm and

Harmeyer, 2008). To minimise this risk, daily feeding during at least the last three weeks of pregnancy is recommended, but it is unclear whether a longer period is beneficial.

Conclusions

There is limited data defining the level of reproductive performance for ewes joined and pregnant in containment areas, but there is some evidence that suggests it is highly variable. Pregnancy rates may be reduced by suboptimal nutrition of ewes, but there is no clear evidence how mob size or structure affects reproductive performance. There is conflicting information on nutritional strategies during the joining period, and a lack of information on the timing and optimal diet for ewes during late pregnancy in preparation for parturition and lactation. Management of condition score is key to optimising pregnancy rates, fecundity, and minimising the risk of ewe and lamb mortality. More data is needed on the potential for late pregnancy nutrition to overcome suboptimal ewe condition. Further investigation to define the level, frequency and causes of wastage associated with confinement feeding of breeding ewes is warranted. Identification of current producer management practices, and their impact, would assist in providing targeted advice to minimise the risk of reduced reproductive performance from ewes joined and pregnant in containment areas. The project team is currently undertaking a producer survey to benchmark current Australian practices.

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9.2 Conference paper

The following manuscript was submitted on 25 May 2020 to the 33rd Australian Association of Animal Sciences (formerly Australian Society of Animal Production) conference, to be held in Fremantle, Perth, on 1-4 February 2021.

Industry perceptions of health issues in containment-fed ewes

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Recent drought has resulted in many breeding ewes being fed in containment areas, and an increased need for information on management. Comprehensive guidelines on sheep management in containment areas are available (DEDJTR, 2018). However, there is a lack of recent information on the current practices used by industry, limiting the ability to target appropriate information for producers. In particular, health issues are a concern given the possibility of ewes being in lower body condition than normal, and the probability of feeding high-grain rations for long periods. The aim of this project was to identify current practices used for containment management, and define industry perceptions of health issues and their management.

A forum was held with six producers/consultants invited from across NSW, VIC, SA and WA, selected for their industry experience and knowledge of containment feeding. The participants were asked to identify typical industry practice, and identify key health concerns. Participants perceived that the welfare of ewes was generally improved by containment feeding, due to frequent monitoring and the provision of maintenance nutrition. Grazing of inadequate pastures, in comparison, was reported to sometimes result in undesirable loss of condition score, which could result in poor reproductive performance. The mortality rates for containment-fed ewes were considered to be dramatically lower than grazing ewes, with an estimated rate of 0.1%, and generally below 1% during the time (variable) in containment. The key causes of death were reported as misadventure, acidosis and pregnancy toxaemia. Other respiratory signs reported were coughing, pneumonia and keratoconjunctivitis (pinkeye), likely resulting from exposure to dust. Occasional incidents of abortion could be traced to listeriosis, toxoplasmosis, or camphylobacteriosis, indicating a need for additional care with feed quality or site selection, a potential benefit from not feeding on the soil, and vaccination as risk management strategies. Other practices which participants reported were not always adopted, or required better guidelines for, are shown in Table 1.

Table 1. Containment-feeding practices recommended, but which were not always adopted by producers.

Issue
Adequately introduce rams as well as ewes to containment ration, care with changing feed batch or quantity
Test for water quality (eg excess mineral, bacterial/algal toxins)
Monitor/test feed quality (eg energy, mould, phytoestrogens, toxins) and monitor ewe condition
Need to provide adequate roughage to reduce shy feeders and prevent acidosis
Feed separate mobs of young, different breeds, or lower condition ewes to reduce shy feeders
Add calcium (and magnesium for last 4 weeks of pregnancy) to high grain diets
Adequate nutrition/fibre/slow change in diet when removing ewes from containment
Vaccinate for enterotoxaemia pre entry and exit
Drench for worms on entry, and monitor faecal egg counts
Provision of shade to prevent heat stress – what is the impact and how much is needed?
Shy feeders need to be identified and removed, but what is the level and how to reduce the incidence?

Many of the health issues reported are similar to those identified in earlier reports (Morbey and Ashton 1990). The findings of the present study indicate that while the health of ewes in containment appears to be generally good and industry recognises many of the contributing factors, there is still a need for on-going provision of guidelines to assist producers to minimise common health issues. In some cases, further research is needed to clarify optimal management.

References

DEDJTR (2018) *Drought feeding and management of sheep – a guide for farmers and land managers 2018*. Victorian Department of Economic Development, Jobs, Transport and Resources, Melbourne.

Morbey A, Ashton B (1990) *Lot feeding of sheep on Eyre Peninsula during the 1988 drought. Technical Report No. 155.* Department of Agriculture South Australia.

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9.3 Prioritisation of research and adoption topics

The research gaps identified and their priority ranking in terms of reproductive performance and health is shown in Table 1. The evaluation for their final ranking is discussed below. Potential industry impact (probable extent of impact on an individual farm x number of containment farms affected), ease and cost for producers to implement, risk of the factor reducing reproduction or health, and the ease of conducting research on the topic were considered.

Table 1. Research topics identified and priority ranking to improve reproductive performance and health

Research Gaps	Forum Priority	Industry impact	Ease to adopt	Cost to adopt	Risk to repro	Research ease	Rank
Optimum level of roughage	high	high	high	medium	high	high	1
What is the maximum safe quantity of feed in one feed? (risk subclinical acidosis)	medium	high	high	low	high	high	2
Optimum mob size – impact on reproduction and shy feeders	high	medium	high	low	low	medium	3
Shade – impact on reproduction	high	medium	medium	variable	medium	medium	4
Optimum feeding method (lick feeders, trail, trough)	low	medium	medium	variable	low	high	5
Condition score and feeding in late pregnancy for lamb survival		medium	medium	medium	medium	high	6
How to manage shy-feeders, and what practices increase the incidence	high	medium	low	medium	low	medium	7
Impact of separation of breed/flock structure (eg age, CS group)	low	medium	high	low	low	high	8
Is vitamin ADE and selenium supplementation in mature ewes beneficial	low	low	high	low	low	low	
Water trough length and flow rate - adaptation to short length	low	low	high	medium	low	low	
Causes of high worm burdens, preg tox, other health issues		low	low	medium	medium	low	
Impact of ram percentage on pregnancy rate/fecundity		low	high	low	low	high	
Impact on conception of handling/feeding ewes during joining and up to 4 weeks post-joining		low	high	low	low	medium	

<u>Optimum level of roughage</u>

The impact of proportion roughage on reproduction is unknown, but is relevant to all producers. Inadequate roughage is known to increase the rate of shy feeders, but also increases the risk of acidosis which is a common problem, and both may be expected to reduce reproductive performance. Changing the level of roughage is practically easy to do. Roughage is typically more expensive per unit of energy compared with grain, so above optimal levels of roughage also increases the cost of feeding. Inadequate roughage creates a high risk for an individual producer of reduced reproduction or health issues, and given some advice to industry that roughage is not necessary, evaluation of the impacts are recommended. Controlled replicated experiments are needed and easily conducted.

What is the maximum safe quantity of feed in one feed?

The impact of high levels of feeding on reproduction is variable, but 20% lower pregnancy rates have been reported. Large feed intakes are known to increase the risk of acidosis, which is a common problem in containment systems, and may also contribute to the known risk of pregnancy toxaemia during late pregnancy. It is easy to change the level of feed, and due to the high risk and prevalence of acidosis, this is a priority topic. Controlled replicated experiments are needed and easily conducted.

Optimum mob size

There is no evidence of any impact of mob size on reproduction if appropriate feeding systems are used, as some producers are currently using mob sizes >1000. Although an area of high industry interest, and the outcomes of this research are applicable across the industry, the risk to reproduction is expected to be low. The level of shy feeders may increase in feeding systems which are not optimal, which may reduce the reproductive rate, but the percentage of shy feeders is typically low. Larger mob sizes reduce labour for feeding, and may reduce the need for fencing and troughs, so would be easy for producers to implement. The risk of poor reproduction from use of suboptimal mob size is low providing adequate monitoring is used. Research to assess optimal mob size would need to include very large mob sizes, which may be difficult to achieve for controlled, replicated experiments. Mob size may also interact with feeding method, so evaluation for key feeding methods is also needed. A viable approach is to collaborate with several producers who each conduct an on-farm comparison of mob size during joining, or at other times if only the incidence of shy feeders is assessed. However, producer engagement may depend on poor seasonal conditions.

Shade – impact on reproduction

A previous report identified a potentially large impact of heat stress on reproduction (0 to 22% fewer lambs born, with additional potential impacts on perinatal lamb survival) for some locations. The impact was dependent on the incidence of heat stress but was based on weather data without the use of shade (van Wettere *et al.* 2020). Containment-fed ewes and rams should have access to shade in hot weather as a welfare standard, so it is unknown whether losses are occurring under these conditions due to heat. The generally high levels of reproduction reported by industry indicate that either the risk to reproduction is lower than suggested, perhaps due to producers generally already using adequate shading, use of longer joining periods which mitigate the risk, or that losses are simply undetected. As examples, for three case studies in Appendix 9.5, ewes were either joined or pregnant during the extreme summer 2019/20, with numerous days > 40°C, but sheep had access to shade and twinning percentages at scanning were above industry average. Without a comparison, it is impossible to determine whether the pregnancy rates of 85 to 97% were reduced by hot weather. The provision of greater or more effective shade for containment systems may increase lamb marking rates if there is a further benefit. However, the cost of improving shade in addition to/replacement of the trees which are commonly used, may be high. The need for an adequate return on investment was noted by industry. The level of potential risk to production across much of Australia warrants further investigation of this topic, although it is noted that the Adelaide research group is working in this area. Since provision of shade is a welfare requirement it is unlikely that pen studies would gain animal ethics approvals to include a treatment without shade. The risks to reproduction may be assessed from monitoring ambient temperatures and heat stress in sheep under field conditions with access to shade and diurnal variation in temperature, to determine whether there is a remaining risk, its incidence, and to define the conditions where further management options are needed to reduce heat stress. As an initial step, this may overcome the difficulty of conducting direct measurement of reproductive responses which are dependent on unpredictable weather.

Optimum feeding method

In comparison with trail feeding, lick-feeding may increase the risk of shy feeders, which may result in reduced reproductive performance in that small percentage of ewes. Feeding on the soil, rather than from feeders, potentially increases the risk of campylobacteriosis and resultant reduced reproductive performance. However, it is not clear how large this risk is nationally, and if ewes are fed past ram removal, vaccination is recommended, so the risk to reproduction is low and related to effects on shy feeding. The purchase cost of numerous lick-feeders may also be high relative to trail feeding, and may require further equipment to fill bins. Lick feeders may reduce feed wastage, but restricted intake is less easily controlled compared with trail feeding. Industry did not perceive this topic as a high priority, despite recognising its moderate potential impact on shy feeders. Murdoch University is currently researching the impact of trail compared with lick feeding on lamb survival, although the grazing situations used mean variability in ewe grain intake and condition score will not be as evident as in a containment system.

Condition score and feeding in late pregnancy for lamb survival

Sub-maintenance nutrition of the late pregnant ewe has a known and large potential impact on lamb survival while excess condition or feeding increases dystocia. Less is known of the impact of condition score when ewes are fed to maintenance requirements. Feeding in very late pregnancy to increase colostrum production is known to increase lamb survival. This topic was not discussed at the forum, but has a medium potential risk on individual farms. However, only a medium industry impact has been allocated because producers avoid lambing in containment where possible, so it is not currently clear that a large number would be containment feeding ewes during late pregnancy. The risk of suboptimal condition score and feeding reducing reproduction is medium because ewes may have entered containment in low condition, and producers may not be accurately estimating nutrient intake. Controlled replicated experiments are needed for this topic and would be easily conducted.

How to manage shy feeders, and what practices increase the incidence

Shy feeders occur in all systems, will have reduced reproductive performance due to weight loss, and are a welfare concern, so have a moderate industry impact even though the percentage affected is generally low. Improved methods of identification would reduce the impact but may increase labour costs. There is a low risk of shy feeders reducing reproduction due to the small percentage affected. This topic is partly addressed in other topics which identify the impact of practices, hence the lower ranking for this topic. Preventing increases in the occurrence, rather than improving management of the small number of affected ewes, can be expected to have a larger impact on reproduction.

Impact of separation of breed/flock structure (eg age, CS group)

This topic was considered an adoption issue at the forum, but there is a lack of data to support a recommendation. Separation of groups may be expected to influence the incidence of shy feeders, and allow more efficient feeding to particular groups. Many producers may already be using these practices.

Several other topics were identified which were considered to have a low impact on reproduction, so have not been prioritised.

Vitamin ADE or selenium supplementation has a variable impact on reproduction, as shown in several research reports. If there is a benefit, it is expected to be situation specific. Supplementation is currently recommended if deficiency is suspected.

The optimal water trough length and flow rate are not known and will vary widely with environmental conditions, meaning prescriptive recommendations may not be relevant to many situations. However, there is no evidence that supply of water is inadequate, and large mobs of sheep are known to adapt to limited trough length. Where supply is adequate to allow free choice of drinking to requirement, it seems unlikely that further research would have any impact. Monitoring of sheep behaviour and ensuring all sheep are able to drink to demand, then modifying trough length if required, seems a practical solution.

Causes of high worm burdens, pregnancy toxaemia and other health issues. Some health issues are sporadic, so their overall impact is low. Others, such as high worm burdens, may be difficult to research. Pregnancy toxaemia appears to be a common problem, but it is probable that research into optimal feeding strategies may partially address this topic. Further investigation is needed to determine when (during containment or after release) and specific situations (feeding practice, condition score, scanned and fed in single or twin groups) when pregnancy toxaemia is occurring, as the causes may be clear, and the incidence reduced by producer awareness and more emphasis on known preventive management.

Impact of ram percentages on pregnancy rate/fecundity. This topic has been well-researched and the impacts are known. The majority of producers also appear to be using higher ram percentages than necessary, above the rates recommended. This is probably to minimise risk. The impact of mating in small mob sizes, so greater potential for poor performance or dominance by one of few rams is less clear, but this could be evaluated as part of studies into mob size. Recommendations to industry need to indicate the risks of lower than optimal ram percentages for some groupings, and the increased risk if very short joining periods are used.

Impact on conception of handling/feeding during joining and up to 4 weeks after joining. Impacts of feeding strategy can be assessed in priority topics. There are reports of handling reducing reproductive rates, although numerous studies also report very high reproductive rates after ewes have been handled, so it is not clear that there would be any effect. Disturbance to mating activity, prolonged time off feed and water and inducing heat stress by activity may all potentially reduce reproductive rates, but producers typically minimise sheep handling, and it is not clear that research in this area would provide a benefit to industry.

The adoption gaps identified are listed in Table 2. Considerations for their ranking is discussed below.

Table 2 Adoption gaps identified and priority ranking to improve reproductive performance and health

Adoption Gaps	Impact	Ease	Cost	Risk	Rank
Ram management/introduction of rams to feed/ram percentage/joining duration	high	high	low	high	1
Introduction to feed	high	high	low	high	2
Genetics/feedtests vary – need to monitor ewes, and frequency of monitoring	medium	high	medium	medium	3
How to manage ewes when removing from containment	medium	medium	low	medium	4
Do not mix stock classes/need for single/twin/triplet separation (shy feeders/feed requirements differ), and benefits of separating condition score groups	medium	high	medium	low	5
Need for health treatments (drench, vaccinate, calcium/magnesium), no need for unnecessary additives	low	high	low	low	6
Need to monitor water quality	low	high	low	low	7
Site selection (toxic, shade etc), durability of facilities, design for other purposes/practicalities	low	medium	medium	low	8

Ram management. The impact of low ram activity or fertility on ewe fertility can be dramatic. They also require preparation well in advance of joining due to the time required for spermatogenesis, and to manage nutrition to achieve optimal condition at joining. Importantly, ram preparation for containment joining is sometimes forgotten. Joining duration is key to enabling targeted management and also to mitigate against the risk of suboptimal fertility. Ram and joining management is easy to achieve and low cost, but issues with rams are a common problem, and relatively high risk to breeding systems.

Introduction to feed. Acidosis is a common problem in containment systems. Mortality rates can be high, but subclinical acidosis may be contributing to other health issues. The prevalence and high risk of acidosis mean continued improvement in introductory feeding practices will have a large impact, even though there are currently clear recommendations on this topic.

Monitoring of ewes. Inadequate monitoring of ewes may lead to weight loss and reduced reproductive performance. Poor condition ewes may also be observed and lead to a poor perception of animal welfare by the public. Shy feeders will occur in all systems so this is a widespread risk, although usually only affecting a small proportion of ewes.

Managing removal of ewes from containment. Health issues do commonly occur if transition to grazing is not well managed, and is a known risk.

Mixing of different classes of sheep. Mixing of classes may increase the rate of shy feeders, although there is limited research evidence to support this. This topic provides opportunity to highlight the benefits of pregnancy scanning and more efficient feeding to fetal number, which reduces costs. The risk is relatively low, since most producers don't currently pregnancy scan.

The need for health treatments and feed additives. There is currently clear advice on the need for drenching and vaccination. There is conflicting advice on the need for feed additives, and marketing of products by various suppliers means this will continue. Some producers are not using the necessary additive of lime (calcium) to cereal or grain based feed, which creates unnecessary risk, but it is not known what proportion of producers would benefit from adoption activities and the benefits may be small to the industry.

Monitoring of water quality. Regular monitoring of water is standard husbandry and most producers probably either have adequate water supplies, or are already aware of excessive mineral content or algal blooms, or the potential for a large impact in water becomes contaminated. The benefit to industry of adoption activities is therefore considered small, although continued reminder of potential issues is needed.

Site selection and facility design. Numerous designs are adequate, so adoption activities may assist producers to improve their facilities, but are unlikely to have a large impact on ewe reproduction or health across the industry. Continued reminder of potential issues is needed.

9.4 Draft guidelines for extension

Introduction

Drought or low availability of pasture may require either sale of sheep, or hand-feeding for either short or prolonged periods. Breeding ewes have the potential to produce lambs and future income, and may be very expensive to replace later if sold. In this situation, a decision needs to be made of whether the resources (funds, labour, equipment, mental resilience) are available to feed ewes for an estimated length of time, or whether it would be better to sell and buy back in when conditions improve. Some producers are now also using containment feeding as a regular strategy to maintain ewes over dry autumn periods when pasture or crop stubbles are typically not sufficient.

Success in maintaining breeding ewes in containment depends on cost-effectively achieving high sheep welfare and optimal lamb marking rates. These guidelines have been prepared based on scientific evidence, to assist in decisions specific to managing breeding ewes and potential effects on health and lamb marking rates.

Is reproductive rate reduced if ewes are containment fed?

Most producers report ‘good’ levels of reproduction from ewes which have been kept in containment areas at some stage. Pregnancy or marking rates may be higher than if ewes are left in poor pasture conditions as better feeding and closer monitoring mean ewes may lose less condition, and any health issues can be promptly actioned. However, on occasion low pregnancy rates or outbreaks of disease which reduce lamb marking rates do occur. Reproductive performance after containment feeding is variable, as it is under paddock conditions, and it isn’t always clear what has caused low pregnancy or lamb marking rates. Using practices which minimise the risks helps to avoid low performance.

Pen design

Regulatory requirements vary between locations. Further and more detailed information on requirements and design is available elsewhere (Dickson 2020b). Key points are:

The minimum space allowance in outdoor containment areas for heavy sheep is 1.4 m^2/sheep, increasing to 1.8 m^2 per ewe with lambs, as required under the Australian Animal Welfare Standards and Guidelines (2014).

The optimum space allowance for unmated, pregnant or lambing ewes is unknown.

When considering pen size: feeding method, vehicle access, soil type and weather conditions (larger areas get less muddy), and potential for alternative uses may be important.

Provide adequate shade if used in hot weather (>25 ^{O}C) – heat stress may reduce ewe and ram fertility, reduce fetal growth, and reduce lamb survival. Existing trees are often used, but need to be protected from ringbarking. Shaded areas also need air flow to aid cooling – cool night breezes help minimise the impact of hot days.

Shelter against strong and/or cold winds may be desirable, particularly for off-shears sheep.

Ample clean water (up to 10 L/ewe per day in hot weather) is needed. Dams may become boggy and contaminated. The optimum trough length is unknown, but trough length and flow rate of water must be adequate for all sheep to drink to requirement daily. Troughs will need regular cleaning to maintain water quality.

Test water quality if in doubt. High mineral concentrations may not be suitable (see Table 1), and contamination with chemical, bacteria or algae may make water toxic to sheep.

Table 1. Total soluble salt and magnesium concentrations (ppm; where mg/L=ppm) in water and suitability for sheep (source: (SCA 1990))

Total Soluble Salts (ppm)	Magnesium (ppm)	Sheep
>4500	<250	Not suitable for lambs
4500-6000	<250	Suitable for lactating ewes
6000-15000	<500	Suitable for non-lactating adult sheep

Containment limits sheep walking long distances looking for feed, so reduces energy use and feed requirement. Existing small paddocks or holding yards may be suitable rather than building special facilities for infrequent use.

There is no one optimal pen design. Consider feeding method (trail, trough, self-feeders), access to provide feed (enter the pen or over the fence), ease of feeding (separate or rotating pens allow safer access to feed).

Site selection: consider freedom from chemical contamination, freedom from toxic plants, low risk of fire or waterlogging, access to sheepyards and feeding equipment, existing shade, impact on surrounds.

The optimum feeding method, if there is one, is unknown. Trail feeding on the ground is often used, but is best in dry conditions with hard-packed soil. Trail feeding may increase the risk of some diseases (eg campylobacter, if ewes are fed post-joining and not vaccinated), but needs minimal equipment and trail length is easily adapted to different mob sizes. Various forms of belting can be used to avoid feeding directly on the ground. Trough systems are an alternative, but will require regular cleaning. Self-feeders, either purchased or home-made, protect feed in wet weather, but may be expensive, require more equipment to efficiently fill, and may be more difficult to control the quantity fed, and typically result in more variable feed intake.

Simple feeding systems work. Many producers successfully feed grain and hay separately, so feed mixers and processing is not required. Processing of grains for sheep increases the risk of digestive upsets.

Mob size

The optimum mob size for breeding ewes in containment areas is not known. Some producers successfully feed mobs >700 ewes. Small mobs may not use rams efficiently, and where only 2 or 3 rams are used per mob, may increase the risk of individual rams reducing pregnancy rates. Larger mob sizes may reduce labour/equipment costs, but increase the difficulty in identifying and removing shy feeders. Larger mob sizes may also increase the rate of shy feeders if access to feed is not optimal. Further research is required.

The importance of monitoring

Regular monitoring of ewe health is important to avoid small issues becoming larger welfare issues, to reduce associated costs, to minimize any reduction in performance, and to achieve targets for reproductive performance. Individual sheep should not fall below condition score 2.0, to maintain welfare, and the mob average needs to be above this to prevent the lower end of the mob falling too low in condition. Monitoring is particularly important for containment as ewes may be in lower condition than normal when feeding starts.

Feedtests are a guide only. Factors such as genetic variability, weather conditions, accuracy of determining quantities fed, and individual variability between sheep all influence whether the quantity fed is adequate. Regular monitoring of condition score is the best means to assess whether feed quantity needs to be adjusted. Weighing of pregnant ewes is not useful because weight increases due to fetal growth, so ewes may lose condition (fat) whilst gaining weight.

Monitoring the condition score of approximately 50 ewes per pen gives a guide to the average mob performance. However, a common issue with containment feeding is shy feeders – sheep which do not eat enough so lose condition. All ewes need to be monitored so that these ewes can be removed and managed separately. Visual monitoring may not be adequate if ewes have long wool.

Monitoring every 2 to 3 weeks is recommended, particularly when ewes are first introduced to containment areas, to avoid large reductions in condition in any individuals. However, the best methods for monitoring mobs and identifying shy feeders early are not clear.

Ewes identified as shy feeders should be removed and either fed in a separate pen, where they may well start eating, or returned to paddocks where they still may need feeding, but are in a more natural environment. Shy feeders seem to occur at an average rate of about 5%, but can occur at higher rates. Ewes which have been introduced to the specific type of feed used as lambs with their mothers, or at a time prior to containment feeding, are likely to recognise the feed and adapt to feeding more quickly than those that have not. This can prevent a 2 to 3 week delay from introduction to eating well.

Any ewes with health issues may need to be removed and placed in a separate pen for easy monitoring, access for treatment, or they may need to be humanely destroyed.

Separation of groups

There is not clear data that separation of specific groups improves reproduction or health. There is some evidence that different breeds may be best maintained in separate pens, as crossbreds may tend to dominate Merinos at feed troughs.

Younger (lambs, hoggets) ewes may be best penned separately because their lighter weight means their feed requirements differ from adult ewes.

Ewes in lower or higher condition score may also be penned separately to allow feeding to increase or reduce condition score. However, since most sheep in a mob will be in fairly similar condition, this may not be necessary.

What and how much to feed

Cereal grains and hay or straw are typically fed in containment areas due to their availability. However, a wide variety of feeds may be used. Be aware that meals and high oil content feeds should not be fed at high percentages of a ration. Key points to consider include:

Ensure feeds used are free from chemical, mould, contamination or other toxins which may cause disease or reduce reproduction.

The minimum energy and protein requirements vary for the frame size, stage of pregnancy, and expected number of lambs per ewe. The minimum protein requirement of unmated and early pregnant ewes is about 7%; this increases to 12% for the last 6 weeks of pregnancy and during lactation. Examples of energy requirements are shown in Table 2. Requirements increase after lambing. Detailed feeding guides are available on state department of agriculture websites.

The quantities fed need to be adjusted depending on whether single and twin-bearing ewes are fed in separate mobs, and with the expected duration of lambing. Most (70%) of ewes are expected to lamb in weeks 3 to 5 for non-teased spring-joined (before February), or in the first 3 weeks for autumn-joined (from February) flocks. Scanning and separation on fetal age as well as fetal number will allow more precise feeding to requirements, where ewes are fed during the last 6 weeks of pregnancy. If ewes are not scanned, the proportion with twin foetuses will need to be estimated – on average this is 30% in Merino flocks, but varies widely.

The quantity of feed may also need to be increased in cold weather, if ewes have < 3cm wool combined with cold weather, or if feed is trampled so not eaten. Monitoring feed wastage and ewe condition is key to ensuring feed is adequate.

Guides to energy and protein contents of feeds are available from state department of agriculture websites (eg (DEDJTR 2018)), but quality varies widely for the same type of feed, so getting a Feedtest done is a safer option to ensure feed requirements are met.

Grain is often cheaper per unit of energy than hay. A minimum of 10% roughage is recommended to maintain rumen health. Higher levels of roughage (20%) may be needed in lactation to promote milk production, but the optimum is unknown. Avoid high percentages of low quality roughage during late pregnancy and lactation as this may prevent ewes eating enough to meet energy requirements. Lupin grain contains sufficient fibre to be fed alone, but is usually expensive.

Table 2. Daily maintenance metabolisable energy (MJ ME/day) requirements of 50 or 60 kg frame size ewes in condition score 3 at different stages of pregnancy, not grazing. Calculated using SheepExplorer software (CSIRO)

	Medium frame ewe (50 kg)		Large frame ewe (60 kg)	
Day of pregnancy	Single fetus (MJ ME/day)	Twin fetus (MJ ME/day)	Single fetus (MJ ME/day)	Twin fetus (MJ ME/day)
0	7.5	7.5	8.3	8.3
70	8	8.5	9	9.5
90	8.8	9.7	9.9	11
110	9.9	11.7	11.3	13.4
130	11.8	14.9	13.6	17.3
150	14.5	19.5	16.8	22.7

Grains and cereal/grass hays contain insufficient calcium. Add 1 to 1.5% limestone and salt to feeds, or supply a 1:1 mix of limestone and coarse salt as a loose lick. Magnesium requirements increase during late pregnancy and lactation, so add 1 to 1.5% causmag to feeds for the last month of pregnancy and during lactation. A loose lick of limestone, causmag and salt in the ratio 1:1:1 reduced the risk of hypocalcaemia and hypomagnesaemia which may otherwise cause ewe mortalities.

Urea is sometimes used with low-protein feeds to increase nitrogen supply to promote rumen microbial protein. Avoid using urea at more than 1% during joining, as this may cause loss of embryos and reduced pregnancy rates.

Sheep must be introduced to grains and grain-based pellets slowly to avoid acidosis. The addition of 1% limestone will reduce the risk, but adequate introduction to grain is the key. It will take 2 to 3 weeks to introduce the final quantity of grain. Feed daily, starting at 50 g/ewe/day, 100 g on day 3, and increase by 100 g/ewe every second day. After day 14, sheep can be fed every second day to reduce labour. Ensure that ample roughage is available during introduction, and reduce the quantity as the grain increases. Other feed additives are unnecessary if ewes are adequately introduced.

Changes in type of grain or batch of grain also need to be gradual to avoid acidosis. Mix batches over several feeds.

Reduce shy feeders by feeding straw rather than hay. High levels of straw should be avoided in late pregnancy and lactation as they will limit energy intake.

Feeding every 2nd or 3rd day, rather than daily, reduces the number of shy feeders. However, ewes should be fed daily (or have constant access to some feed) during at least the last 3 weeks of pregnancy to reduce the risk of pregnancy toxaemia.

The optimal feeding method is unclear. Simple feeding systems (grain and hay provided separately) are effective. Trail feeding may reduce the number of shy feeders compared with self-feeders, but this is unknown. Trail feeding on the ground reduces costs for equipment, but is most suited to hard-packed soil types in dry weather. Feeding on the ground may increase the risk of some diseases. Feeding systems need to be long enough so all sheep can gain access to feed.

Ram preparation

Healthy, working rams are critical to getting good lamb marking percentages. Sperm production takes around 50 days, so prepare rams for joining at least 2 months before joining.

Aim for rams to be in condition score 3 at joining. Aim for condition score 3 of rams at joining. Rams ≤ 2.5 or ≥ 4 produce less or lower quality sperm.

Increase sperm production by at least maintenance nutrition for 7 weeks before joining. Sperm production takes around 50 days. Feeding 500g/ram/day lupin grain for this time in addition to the normal ration or grazing will increase semen production, particularly where grazing dry pasture. There may be little benefit for British-breed rams during spring or if grazing ample green pasture.

Rams may be deficient in vitamin A if no access to green hay or pasture, or maize grain for 3 months. Consider a vitamin A injection at least 2 months before joining.

Shear rams to avoid long wool at joining. Short wool reduces heat stress in humid locations, while increasing length to 4 cm reduces heat stress under dry heat. Protect rams from heat stress for at least 2 months before and during joining with ventilated shade to protect ram fertility.

Introduce rams to the containment ration of ewes slowly, 2-3 weeks before joining, to avoid acidosis from high grain diets

Vaccinate rams for pulpy kidney and other clostridial diseases before feeding, and monitor faecal worm egg counts and if needed drench before entry to the containment area.

Protect rams from flystrike, which may reduce mating activity and fertility for several weeks after the event. Preventive chemicals may assist if joining during warm weather. Rams fighting increases the risk of poll strike.

Joining management

Ensure ewes are drenched if needed and vaccinated against pulpy kidney (eg 3 in 1, 6 in 1) before the start of feeding.

Consider selling or not joining ewes if the increased costs of feeding pregnant and/or lactating ewes is too high. Alternatively, ewes may be joined, and decisions made before late pregnancy, depending on improved pasture conditions, as to whether some or all ewes can be retained through lambing.

Use enough, healthy rams. Avoid mating ewes to single rams as some rams have poor fertility or aren't good workers. A rate of 1% + 1 extra ram for each adverse factor is generally adequate for a 5 to 8 week joining. A higher rate of 2% is recommended for ewe lambs and maiden ewes, and for shorter joinings may increase the pregnancy and twinning rate.

Join ewe lambs, maiden ewes, and adult ewes in separate mobs to avoid lower pregnancy rates in young ewes and/or a more extended lambing. Young ewes do not compete for rams as well as adult ewes.

Joining for 5 weeks in autumn (from February) or 7 weeks in Spring (before February) allows ewes two chances to mate. Shorter joinings risk less ewes falling pregnant. Longer joinings may not increase pregnancy rates, and make it more difficult to efficiently manage nutrition in late pregnancy and after lambing. The use of vasectomised teaser rams for 2 weeks prior to joining for spring to early February joinings allows the length of joining to intact rams to be reduced to 5 weeks.

A minimum condition score of 2 at joining is needed to avoid low pregnancy rates and potential welfare issues in later pregnancy. Ewes in condition score 3 are expected to have higher twinning rates so produce more lambs, although genetic variation means there may be no further benefit above score 3 or score 2 in some lines. Avoid having adult ewes ≥ CS 4 as these need to lose condition in early to mid pregnancy to reduce the risk of later pregnancy toxaemia and dystocia. Pregnancy rates for ewe lambs may increase up to CS 3 to 3.5 at joining.

Ewes without any access to any green hay or pasture for 2 months may be deficient in vitamin A. Other minerals may be deficient in some areas. Consult a veterinarian.

Ensure ewes are adapted to feeding before joining where possible, to reduce the risk of weight loss during joining, which will reduce twinning rates.

Avoid feeding well above maintenance during joining as this may reduce pregnancy rates.

Provide adequate shade during joining and pregnancy. Heat stress can reduce ewe and ram fertility, and reduce fetal growth, potentially reducing lamb survival after birth.

Managing pregnant ewes

Vaccination pre and post joining, then an annual booster against campylobacteriosis is recommended particularly if ewes are fed on the ground.

Pregnancy scanning is recommended from 50 days after rams are removed. Detecting singles and twins as well as non-pregnant ewes allows separation and more cost-efficient feeding as the energy requirements differ in late pregnancy and after lambing. Fetal aging may also allow ewes to be separated and more efficiently fed to requirements, but depends on the accuracy of the scanner.

If possible, where ewes are brought into containment during pregnancy, adapt ewes to feeding before the last 6 weeks of pregnancy to minimise the risk of acidosis or disturbances causing pregnancy toxaemia.

Adequate feeding of ewes during late pregnancy and lambing is critical for lamb survival. Feed to maintain ewe condition score during late pregnancy. Loss in ewe condition in the last weeks of pregnancy may reduce milk production, produce poor ewe behaviour after birth, and reduce lamb energy stores, all or which will reduce lamb survival. The reduction will be greater for twins, and in cold weather.

Excess gain in condition score during late pregnancy, or overfat (condition score 4) ewes increases the risk of large lambs and lambing difficulty.

Provide adequate shade during pregnancy. Heat stress can reduce reduce fetal growth, potentially reducing lamb survival after birth.

Vaccinate against clostridial diseases (eg 6 in 1) 4 – 6 weeks before lambing to protect lambs after birth.

Avoid shearing or any other activity which restricts feed intake for prolonged periods during the last 6 weeks of pregnancy, as this may trigger pregnancy toxaemia. If ewes have to be yarded (eg for vaccination) or mustered to other paddocks, limit the time off feed and handle gently.

No data on management of lambing in containment is available. However, lambing in containment is undesirable if paddock lambing is an option, due to potential mismothering associated with feeding and high stocking rates.

Removing ewes from containment

When removing ewes from containment, vaccinate for pulpy kidney. Feed before release, and adapt to pasture over several days by increasing grazing time, or by continuing to feed. Ewe losses from pregnancy toxaemia have occurred where pasture was inadequate; supplementary feeding may still be needed.

Health

Prevention is best. Following the guidelines in this manual will minimise the risks to health. Consult a veterinarian to diagnose and advise on treatment if health issues occur.

A range of health issues are detailed on state department of agriculture websites and elsewhere (Besier *et al.* 2010; Dickson 2020b). The mortality rates in containment systems are reported to by generally very low (<1%), however, problems sometimes occur. The key health risks with containment feeding breeding ewes are:

Acidosis (grain poisoning)

<u>Symptoms</u>: soft manure, tucked up appearance, reluctance to walk, lameness, lethargy (dullness), death.

<u>Treatment</u>: Remove affected sheep from grain and offer hay. Drench with bi-carbonate of soda (15 g/L water). Seek veterinary assistance for large numbers or valuable sheep.

<u>Prevention</u>: Introduce grain slowly over 14 to 21 days. Mix new batches of grain or new types of grain over several feeds to avoid a sudden change. Monitor manure to make sure sheep are adapted to the grain before increasing the quantity. Ensure adequate roughage (eg straw) is available. Use lower-risk grains. Lupin grain is relatively safe, but is still capable of causing acidosis. The risk increases from oats < barley < triticale < wheat.

Enterotoxaemia (pulpy kidney)

Symptoms: Sudden death. May be seen with violent convulsions prior to death.

Prevention: Vaccinate against clostridial diseases (eg 3 in 1, 5 in 1). Two vaccinations, an initial vaccination, followed by a booster 4 weeks later, but prior to entry to containment, are required. If fed in containment for many weeks, further vaccinations may maintain a low risk. High grain or energy intake (including lush pasture) increases the risk. Sudden changes to diet increase the risk. Release ewes from containment to pasture gradually, or continue supplementing for a few days after release.

Pregnancy toxaemia (twin lamb disease)

Symptoms: Dullness in the early stage, blindness, star-gazing, before ewes become recumbent. The condition develops over several days. A large proportion of the flock may be affected.

Treatment: Unless treated in the early stage is usually not successful. Oral treatments with liquid energy supplements (eg Ketol) may be successful in the early stage.

Prevention: This is a metabolic disease where if energy intake is not adequate, the sheep breaks down fat reserves, resulting in toxic production of ketones. One affected ewe may be a sign that a large proportion of the flock is at risk. Ensure ewes are fed to energy requirements in late pregnancy, and are not removed from feed for long periods. Minimise stress and handling. Avoid having ewes excessively fat (condition score ≥ 4) or thin (<2) in late pregnancy. Ewes with twin or multiple foetuses are at greater risk due to their higher energy requirements, as are old ewes. Lameness or other factors such as a poor weather event that restrict ewe intake may also lead to the condition.

Hypocalcaemia

Symptoms: usually in late pregnant or lactating ewes, but can occur in other classes. Muscle tremors or staggering, before the sheep becomes recumbent (sits, falls over) and refuses to rise. Symptoms develop rapidly. A large proportion of the flock may be affected.

Treatment: calcium injection (eg 4 in 1). If treated early, recovery can be rapid, but repeated treatment and change to diet may be required.

Prevention: Grains and cereal hay/forage have an imbalance of calcium to phosphorus, resulting in calcium deficiency in the sheep. In addition, calcium requirements are increased in late pregnancy and lactation. Add 1-1.5% ground limestone to grains and cereal/grassy hays. A loose lick of 1:1 limestone:salt is an alternative. Avoid stress such as long mustering, transport,

Hypomagnesaemia (grass tetany)

Symptoms: Muscle tremors, violent convulsions and death. Progression is often rapid, and easily induced by disturbance such as mustering. Occurs in lactating ewes.

Treatment: Injection with calcium and magnesium solutions may be effective.

Prevention: The condition is caused by low magnesium intake. Magnesium requirements increase particularly with milk production. Cereals contain low magnesium, and hypomagnesaemia is often seen when grazing cereal forage. The addition of 1% Causmag to feeds, or the use of a loose lick of limestone:Causmag:salt in the ratio 1:1:1 during late pregnancy and lactation reduces the risk when ewes are fed deficient diets.

9.5 Case studies

9.5.1 Case study 1 Jaffa Containment – The Journey

Producer: Anthony Shepherd

Location: 'Jaffa' Cootamundra NSW

Enterprise: self-replacing Merino and Merino joined to Poll Dorset rams

Number of ewes containment-fed
In 2020: 1119

Reproductive performance
90% pregnant; of early pregnant ewes – 45% singles and 55% twins

Management
Ewes were joined for 5 weeks 17th November to 23rd December 2019 while grazing dryland lucerne. Wheaten hay was fed from 23rd December 2019 to introduce ewes to the diet. On 1 January 2020 all mobs were in excellent condition (maidens 3.1 to 3.5, weighing 59.8 kg; adults 3 to 3.3, 65 kg). The maiden ewes (242) were placed in a 11.6 ha paddock containing dry lucerne; the adult ewes joined to merino rams (426) were placed in a 2 ha containment yard and transferred onto wheaten tailings hay; a mob of adult merino ewes joined to Poll Dorset rams (451) was placed in a 70 ha back hill paddock containing some dry pick, and was fed wheaten tailings hay. A restricted quantity (200g/head/day) of barley grain was fed to all mobs from 6 January using self-feeders, in addition to the ad libitum hay. By scanning on 7 Febuary, the mob joined to Poll Dorsets had lost condition to average 2-7 to 3.2, while the other mobs had maintained condition. After scanning, all early pregnant maiden and adult ewes joined to Merino rams were placed in a 2 ha containment pen, and the quantity of barley grain increased. The early mob joined to Poll Dorsets was placed in the 11.6 ha paddock and fed the same barley/hay ration. By estimating fetal age at pregnancy scanning, a lambing duration of 20 days was expected from these mobs. All ewes scanned as late pregnant were removed and fed lucerne hay in a separate paddock with oat regrowth. From 21 February the barley grain was replaced with lupin grain (ran out of barley and lupins has higher protein), and feeding continued until 17 March, when ewes were removed, shorn and allocated to lambing paddocks. Only 2 ewes died during the whole feeding period. No additives were given to the ewes while in containment. Both the wheaten cereal hay and wheaten tailings were extremely green in colour with good available trace elements and minerals in the feedtests.

Reproductive performance

Having ewes in good condition at joining meant most ewes conceived, with a good twinning rate at scanning (table below).

	242 maiden Merino ewes and 426 adults joined to Merino rams 19 months and mixed age	Merino ewes joined to Poll Dorset rams Adult mixed age	Total flock
Not pregnant (%)	6.5	14.6	9.8
Early singles (%)	35.4	38.8	36.8
Early twins (%)	48.5	38.1	44.3
Late lambs (%)	6.7	8.4	9.1
Fetus per ewe joined (%)	147	126	138

Lessons learned

Make sure ewes are in good condition (condition score 3) for joining and maintain during pregnancy
Separate ewes in lower condition and feed separately
Self-feeders are used in containment where they can be filled from outside the containment yard.
Make sure ewes are introduced to grain slowly with good access to hay, to avoid acidosis

Key messages

Pregnancy scan and fetal aging allows ewes to be fed to requirement, saving feed
Containment feeding saves energy lost from walking around big paddocks looking for feed – so saves in feed costs
Start feeding before ewes lose a lot of condition
Condition scoring a sample of ewes (identified so the same ewes each time) in the mob throughout the journey of being in containment gives an excellent guide to whether you are meeting the ewes energy requirements.

9.5.2 Case study 2

Producer name: Derk Meurs
Location: “The Pinnacles” Wagga Wagga NSW

Enterprise: Merino ewes, joined to Poll Dorset (adult) or White Suffolk (maiden) rams

Number of ewes containment-fed
In 2020: 13,000

Reproductive performance
Adult ewes: 85% pregnant; of pregnant ewes – 55% singles and 45% twins
Maiden ewes: not scanned this year to avoid the risk of staff being exposed to COVID-19
Heat stress had no impact on reproduction rates this summer (2020), but in 2019, we did experience above 40 degree weather for 2 weeks that did see lower than normal reproduction rates.

How ewes are managed
The ewes had been shorn, vaccinated with 6 in 1 and drenched in September/early October, and were fed in containment from early December through to March. Adult ewes were joined on 1 December, and rams removed in mid March. This long joining was used because not all ewes were on the property or joined until January. Maiden ewes are joined a month later than the adults. A ram percentage of 1% was used for both adult and maiden mobs, but the rams were swapped with fresh rams every 2 weeks. At scanning, most ewes had mated during the first 6 weeks of joining, and mobs were separated and fed as singles and twins. The ewes were again vaccinated at scanning. Ewes were removed from containment at least a month before the start of lambing, to minimise any risk of nutritional issues causing pregnancy toxaemia.

The ewes were not allowed to fall in condition score before containment feeding started, to maximise lambing rate and were in condition score 3 or better at the start of feeding, with slight gain in condition by the end of feeding. Derk uses 1.6 to 2 ha paddocks, and recommends a maximum of 700 ewes per pen. He has found this works well, and while he has fed mobs of 1500 ewes, large mobs can increase the number of shy feeders. Each paddock has adequate shade supplied by trees. Concrete water troughs are used and are 4 m in length, and cleaned every third day. Ewes are started on grain at 200g/day of feed which was steadily increased over a period of 2 weeks. During this time, a close eye is kept on the sheep to monitor for signs of digestive upsets. The ewes were fed barley grain trailed on the ground over the fence from a truck, which makes feeding easy. Barley was fed at 4 kg/week per ewe, increasing to around 6 kg/week pre-lambing as energy requirements increased with pregnancy. This level was slightly above maintenance. Cereal straw is also provided *ad libitum*. The grain was fed daily for 6 days per week. Grain was not fed on day 7 while ewes clean up any remaining grain but also have access to straw, to prevent wastage of grain. Salt and lime were also provided *ad libitum* in tyres to correct the calcium deficiency in cereals, and a magnesium supplement (Causmag) was also included for the last two months before lambing to reduce any risk of grass tetany.

The tail end of each mob is drafted out every 2 weeks and these ewes returned to grazing paddocks where they are fed. This is particularly needed early during feeding due to some ewes not adapting, but these ewes tend to settle down, eat and mate in a normal paddock. Drafting on visual condition is needed to efficiently get through the large number of ewes.

When the ewes were released from containment, they were fed first, let out to graze, then placed back into containment over about 3 days. This was because they were released onto green Lucerne,

where a sudden change in diet might cause health problems; if they were released onto dry pasture, Derk would have let them straight onto pasture.
No health issues were observed with ewes, other than some shy feeders as expected.

Lessons learned
Water troughs need to be cleaned 2 or 3 times a week as they get very dusty.
Too many rams causes fighting and ram death or injury, possibly because they can't get away from each other. Derk used to use 2% rams, but has found 1% rams, swapped with fresh rams every 2 weeks, reduces fighting and still gives good pregnancy rates.
Sheep like a routine. Derk has observed that feeding sheep later in the day when it is hot means sheep don't come and eat then, but eat when it cools down, gorge themselves and this results in deaths from acidosis. He now feeds early morning (7am) and has no issues with acidosis or high mortalities.

Key messages
Avoid too many rams – 1% rams minimises fighting and gives good results
Remove the tail end of ewes regularly to ensure high welfare – some ewes do not adapt to containment feeding
Feed in the morning to minimize the risk of acidosis

9.5.3 Case study 3

Producer name:
L & V Herbert (home of Karrawarra Pastoral http://www.karrawarra.com.au/)

Location: Eurongilly, NSW

Enterprise (breed):
Karrawarra Highlander (maternal composite) and self-replacing maternal flock turning off trade lambs

Number of ewes containment-fed
In 2020: 5,387 ewes

Reproductive performance
Adult ewes: 97% pregnant; of pregnant: 22% singles, 78% multiples
Hoggets: 92% pregnant; of pregnant: 35% singles, 65% multiples
Lambs: not scanned at time of writing

	Single	Twin	Triplet	Quad	Dry	Total ewe number	Fetus/ewe scanned (%)	Non-pregnant (%)
Adult ewes	388	1330	56	3	47	1824	177%	3%
Hoggets	416	760	15	0	97	1288	154%	8%

How ewes are managed
Ewes were introduced into containment pens around Christmas time and rams (1% (+1) to adult ewes, 1.5% to lambs)) were introduced mid-February for six weeks. At the completion of joining there had been enough rain to let ewes out of containment.

Containment pens were constructed in an area that is not suited to grazing or cropping. Large gums provide generous shade and fallen limbs have been observed to provide environmental enrichment. Shallow concrete troughs which are cleaned three times a week provided constant fresh water. Pens 150 m X 60 m contained approximately 500 ewes fed at 1.5 kg/ewe/day (3kg/ewe/feed). Mixed age ewes were run with hoggets, but ewe lambs were penned together as two larger separate groups. Ewe lambs are not run with older ewes until after they have had their first lamb due to their different management needs.

Sheep were fed a total mixed ration from a feed mixer of 66% canola silage (fine chop), 17% barley straw and 17% cereal grain (wheat, barley or triticale) plus salt every second day. Troughs were constructed from rubber belting laid into a metal hoop. This feeding system worked very well, however, after rain events the troughs had to be shovelled out or tipped over with a loader.
Prior to the feed mixer purchase (late 2019) we containment fed ewes with a grain feed trail every second day and fed out bales of canola silage on alternate days. The new system resulted in greater

efficiencies including labour input, extended time to consume ration (satiety) and increased conception rates. We also noticed that ewes did not suffer from acidosis or feed related illness during the acclimation period which was observed last year.

There were no shy feeding issues in hoggets and adult ewes (run and joined together). However, ewe lambs (separate group) were slow to get onto feed. This was helped by decreasing fibre ratio and increasing grain.

Lessons learned
Need to clean feed and water troughs regularly.
Use of a feed mixer and feeding every 2nd day has reduced labour and improved ewe performance.

Key messages
Some producers do not believe roughage is necessary, however, we find sheep seem more content when constant roughage is available. The benefit of the total mixed ration was sheep took about one and half days to finish their ration as opposed to previous years when grain would be finished in a matter of hours and there was a longer period until the next feed. We believe this also helps combat acidosis and metabolic upsets as well as decreasing shy feeding numbers as there is always feed available.