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Nutritional management of Dorpers for reproduction and growth in Australia: A literature review

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Abstract

This review aims to gather information on the reproductive and growth potential of Dorper sheep and how to reach this potential through nutrition and management. It also investigates whether Dorpers possess adaptive qualities to arid environments that may have production benefits under Australian grazing conditions.

Dorpers have a high reproductive capacity mainly due their fertility, early maturity and their ability to breed year-round. There is currently no optimum nutritional management strategy for the Dorper. Breed differences in nutrient partitioning between Merinos and Dorpers suggest a nutritional regime that allows more fluctuation in live weight of the Dorper ewe than is recommended for Merinos may allow feed resources to be used most efficiently while not compromising the ewe or her lamb.

Dorper lambs perform well on high quality diets, but they may also be able to utilise lower quality food more efficiently than some other breeds such as the Merino due adaptations in rumen physiology. Dorpers and Merinos also seem to differ in their grazing habits and diet selection.

This review identifies two main priority areas for future research:

1. Develop a nutritional management plan to optimise reproductive rates
2. Investigate the ability of Dorpers to utilise low quality roughages and the possible production benefits under Australian grazing conditions.

Executive summary

The Dorper breed of sheep has become very popular throughout Australia since they were first introduced in 1996 from South Africa. The main qualities of the breed that attract farmers are that they are an easy care hair sheep with a high reproductive rate and growth potential. Dorpers are also thought to be hardy and well suited to tough grazing conditions since they inhabit harsh environments in Africa. Even though there has been a large increase in the numbers of Dorpers in Australia, there is little information on reproduction and nutrition of this breed under Australian conditions. It is also unclear whether Dorpers possess adaptions to harsh grazing conditions that could give them production advantages over other breeds under grazing conditions in Australia, particularly in variable climates.

This review will do four main things:

- Collate the information available on the reproductive and growth traits of the Dorper and compare these traits to other breeds, particularly the Merino since it is the most common breed in Australia.
- Evaluate the best nutritional and management strategies for the Dorper so its production potential can be reached.
- Investigate what adaptive advantages Dorpers may have to utilising low quality foods and whether these are likely to provide production benefits in Australian farming systems.
- Identify gaps in research that warrant further investigation.

The Dorper has a high reproductive potential in both intensive and extensive farming systems. Dorper ewes have high conception rates, are reasonably fecund and their less-seasonal breeding pattern allows them to mate year-round. Maiden ewes can be incorporated into the breeding flock at around 8 months of age and ewes remain productive up until 7 years or older. Dorper lambs also have the potential for rapid growth rates from birth until slaughter. These reproductive characteristics allow Dorpers to produce a large number of lambs per ewe lifetime.

There has been no research conducted on the optimum condition and live weight change of the Dorper ewe that maximises lamb production. Applying the current nutritional management system for Merinos in Australia may not be optimal for the Dorper as it has been shown to result in reproductive wastage when applied to Dorper ewes. Breed differences exist between Merinos and Dorpers in nutrient partitioning and the Dorper has an increased ability to deposit and subsequently utilise body reserves without influencing milk production. Although body condition fluctuations are detrimental for the Merino ewe, in the Dorper ewe they may be an important tool in ensuring the most efficient use of feed resources. Therefore, the first research priority

should be to establish a best-practice nutritional management plan for the Dorper to maximise reproductive rates.

There is evidence that Dorpers possess adaptations to arid environments that may allow them to utilise low quality diets more efficiently than Merinos. There is very limited information available on the mechanisms behind this, but it may be associated with a longer retention time of fibrous digesta in the rumen. There are also differences in the grazing behaviour of Dorpers and Merinos that may allow Dorpers to better utilise the lower quality components of the available diet. However, there is little information on these adaptations, the mechanisms behind them and whether they will translate to production benefits under Australian grazing conditions.

There are two main research priorities for the production of Dorpers in Australia:

1. Develop a nutritional management plan to optimise reproductive rates
2. Investigate the ability of Dorpers to utilise low quality roughages and the possible production benefits in Australia.

Dorpers have the breeding and growth potential to help fill the increasing demand for Australian sheepmeat and provide domestic markets with a much needed continuality of supply of lamb with good carcass qualities. The Dorper may also have a role to play in maximising the resilience of livestock production systems to variations in climate through their adaptability to harsh grazing conditions. However, more research into this breed is needed for its potential in Australia to be realised.

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1. Introduction

The Dorper breed of sheep originates from South Africa and its main parent breeds are the Dorset and the Persian, hence the name “Dorper”. This review collates mainly peer-reviewed research papers that have been published on the reproductive and growth traits of the Dorper and its adaptions to harsh environments. The majority of this research has been conducted in South Africa, but in this review there is an emphasis on how these results might apply to Australian livestock production systems. Therefore, during the review it will be noted when Australian studies are referred to. This review aims to:

- Collate the information available on the reproductive and growth traits of the Dorper and compare these traits to other breeds, particularly the Merino since it is the most common breed in Australia
- Evaluate the best nutritional management strategies for the Dorper in order to reach its production potential
- Investigate what adaptive advantages Dorpers may have to utilising low quality foods and whether these are likely to provide production benefits in Australian farming systems
- Identify gaps in research that warrant further investigation

First in this document, the origins of the Dorper breed are discussed and its history in Australia followed by the main reasons for their increasing popularity. The reproductive statistics available on Dorpers are then examined including average values for major reproductive traits and how these compare to other sheep breeds. The management strategies of the Dorper flock are then discussed with emphasis on the age structure of the flock and mating strategies before the overall reproductive potential of the Dorper breed is summarised.

The review then focuses on the information available on the nutrition of the Dorper ewe during the critical reproductive phases of joining and late pregnancy/early lactation as well as how nutrition effects the duration of post-partum anoestrus. Whether or not the current best-practice system for the nutritional management of the Merino during reproduction can also be applied to the Dorper ewe is evaluated. The growth rates and feed efficiency of Dorper lambs when fed high quality finishing diets is then discussed and compared with other breeds.

The adaptive mechanisms that Dorpers may use to cope under harsh grazing conditions are; alterations in their metabolic requirements, digestive efficiency and their propensity to deposit and utilise body reserves. These adaptations are discussed as well as how they might benefit sheep production under Australian grazing conditions. Other adaptions are also discussed before the

grazing behaviour and diet selection of Dorpers is investigated and how this may differ from Merinos.

Finally, conclusions to the review are formulated and major gaps in the knowledge of Dorper sheep are identified. Recommendations are also made for the focus of further research.

1.1 History of Dorpers

The Dorper breed originates in South Africa where a large proportion of the agricultural land is grazed by sheep. In South Africa, approximately 80% of agricultural land is unsuitable for crop production, while the largest part of this land is not suited to either dairy or beef production (Schoeman et al., 2010). This leaves the largest area of agricultural land in the country best suited to sheep grazing. Thus, there has been, and still is, a large focus on sheep breeding in South Africa.

In the 1930's farmers in South Africa, like many agricultural areas of the world, became influenced by the depression, surplus mutton and a slump in wool prices. In looking for alternate markets for their products, farmers became interested in the potential of exporting of mutton and lamb, particularly to Britain (Milne, 2000). However, original fat-tail breeds of sheep in South Africa could not compete in the export market with the high quality carcasses coming out of New Zealand and Australia (de Waal and Combrinck, 2000). Therefore, in order to capture this emerging market, farmers had to improve the carcass quality of their sheep. However, they did not want to sacrifice the hardiness, easy-care and adaptability of their current sheep breeds since they thrived in the harsh, semi-arid environment in South Africa where other breeds could not survive. This led to farmers experimenting with breeding new types of sheep.

A combination of government researchers and dedicated farmers wanted to breed hardy, easy care sheep with good carcass qualities that could breed year-round. After many crosses with different breeds, a cross between a Dorset Horn ram and a Black Headed Persian ewe was chosen as the main parent breeds, although there may be is some inclusions of other breeds such as the Van Rooy (Milne, 2000). Dorset Horn rams were chosen for their good carcass qualities and reproductive traits such as a longer breeding season compared to other British breeds, high fecundity and fast lamb growth rates (de Waal and Combrinck, 2000). High quality Dorset Horn rams were imported from the UK and Australia during 1937 (Milne, 2000). However, the Dorset Horn was poorly adapted to semi-arid grazing conditions experienced in South Africa which lead to the inclusion of the Black Headed Persian.

Black Headed Persian ewes were chosen because of their outstanding performance under harsh environmental conditions. The Black Headed Persian originally entered South Africa by luck in 1870 when a damaged sailing ship from Somalia carrying one ram and three ewes, had to stop for repairs in Southern South Africa. The sheep aroused interest in local farmers and they were traded for other slaughter sheep (de Waal and Combrinck, 2000). From then on, more Black Head Persians were imported and they became renowned for their ability to adapt to harsh grazing conditions and their propensity to lamb year-round (de Waal and Combrinck, 2000). In 1947 the name "Dorper" was coined from the first three letters of the parent breed's names (*Dor*set and *Per*sian) and the first stud was established in South Africa. The combination of the Black Headed Persians durability and resilience to arid environments, coupled with the superior growth and carcass characteristics of the Dorset Horn has lead the Dorper to be regarded as a hardy breed with good growth and carcass qualities (Milne, 2000).

There are two main types of Dorpers, the Dorper and the White Dorper and while the majority of Dorpers are hair sheep, some produce wool. The Dorper has a white body with a black head (Figure 1), much like the Black Headed Persian, while the White Dorper is completely white (Figure 2). The genetic origins of these two variants of the breed are the same, the different colourings have simply been selected for out of preference (Milne, 2000). Therefore, for the purposes of this literature review, the term "Dorper" relates to both Dorpers and White Dorpers. There has also been a divergence in the type of coat cover in Dorpers and there are both hair and wool types. However, since these types do not differ in any economically important traits (Snyman and Olivier, 2002), they will be considered the same in this literature review. Although there are slight variations in type within the Dorper breed, these differences do not hold economic importance so will not be discussed further.

Figure 1: Dorper ram
(picture courtesy of Jilakin Downs Dorper Stud)

Figure 2: White Dorper ram
(picture courtesy of Jilakin Downs Dorper Stud)

Since 1947, the number of Dorpers in South Africa has increased steadily and in the year 2000, the estimated number of Dorpers in South Africa was 7 million (Milne, 2000). Numerically, the Dorper is the second largest sheep breed in South Africa, behind the Merino (de Waal and Combrinck, 2000). Dorpers now inhabit some of the harshest deserts in Africa, areas in which many other breeds cannot survive (Degen and Kam, 1991). However, they have also become increasingly important in intensive farming systems where they receive much better nutrition (de Waal and Combrinck, 2000). This shows that Dorpers have the ability to adapt to a range of environments which is the main reason why they have been imported to many other countries, including Australia.

1.2 History of Dorpers in Australia

Dorper embryos were first introduced to Australia in 1996 along with other exotic breeds such as the Damara. After their introduction and increased popularity, much concern was raised over the contamination of the Merino wool clip with coloured and kempy fibres. (Young et al., 2002). However, this concern has since abated with farmers strictly adhering to the AWEX code and contamination has been limited. Although other hair breeds have been introduced into Australia, the Dorper has become one of the most popular. The Dorper breed associations currently have a membership similar to the Poll Dorset breed, the dominant prime lamb sire breed in Australia. There is a wide distribution of Dorper studs throughout the sheep producing areas of Australia and they are increasing in popularity (Assoc., 2006). The reasons why Dorpers have become a popular breed in Australia stem from the issues

that have faced and continue to face the sheep industry in Australia. These are low wool prices and high labour costs which favour “easy care” sheep, high prices and demand for sheepmeat and the need to increase sheep numbers for a sustainable sheep industry in Australia (Curtis, 2009).

Easy-care

Dorpers are considered “easy-care” sheep because they are hair sheep that shed their fleece and do not need to be shorn, crutched or mulesed. The low price of wool in Australia from the 1990’s until recently, has led to the increased popularity of hair sheep that do not require shearing which decreases labour costs (Young et al., 2002). Because of their plain body, they are much less susceptible to flystrike on the breech area so do not need to be crutched or mulesed (Young et al., 2002). This benefit became particularly influential when an international anti-mulesing campaign was launched by animal rights groups in 2004 which put farmers under increased pressure to stop the practise of mulesing. Dorper sheep are also popular with farmers who do not have shearing facilities on their farm such as small land-holders. Taking the wool and breech fly-strike labour costs out of sheep production has been an advantage to farmers in breeding Dorper sheep over traditional Merinos (Young et al., 2002).

Sheepmeat production

In contrast to wool prices, prices for sheepmeat have grown since the 1990’s both in export and domestic markets. The domestic market accounts for of Australia’s lamb production, with the other half being exported to areas such as the Middle East, the USA and China (MLA, 2012). The proportion of lamb production exported from Australia has more than doubled since 1990 (ABARE, 2004). Because of the seasonality of pasture availability coinciding with Merino sheep reproduction, domestic abattoirs often have to decrease production or at times shut down when supply of lambs is limited, usually during winter. Dorper sheep are less-seasonal with their breeding patterns so lambs can be produced throughout the year, not just in spring as occurs in Merino production. This allows farmers to capitalise on the high out-of season lamb prices which helps to offset the higher cost of feeding at this time when pasture availability is low. This continuality of supply of lambs could help domestic abattoirs remain viable throughout the year which is important for both the domestic market and the expanding live export markets of Australian sheepmeat. However, if we are to keep these markets, there is a need to increase sheep numbers in Australia.

Increasing reproductive rates

Sheep numbers in Australia are at their lowest since 1905 (ABS, 2011a), but they are showing signs of recovery (ABS, 2011b). The low price for wool and much higher profitability of cropping compared to livestock has caused many farms to decrease sheep numbers in favour of crops. In the wheatbelt of Western Australia, the average operating profit over 5 years of cropping is $58/ha, compared to grazing sheep which produced an average loss of -$24/ha (Farmanco Profit Series, 2011). However, with the increasing demand for Australian sheepmeat, sheep numbers need to increase in order to meet existing and emerging markets for the industry to be sustainable (Curtis, 2009). The Dorper's high reproductive rates may assist in this recovery. Their prolificacy, early maturity and ability to breed all year-round means that high reproductive rates can be achieved. Increasing the numbers of sheep in Australia through high reproductive rates will help secure the long term viability of the sheep industry. However, the Dorper can only help achieve this if their management strategies are optimised to achieve their reproductive potential.

2. Reproductive potential and management strategies of Dorpers

The major indicators of reproductive performance in sheep are conception rates, fecundity, lamb survival and pre-weaning lamb growth rates to reach mating weight. In this section, the information available on these main reproductive parameters in the Dorper sheep will be discussed followed by comparisons with other breeds. Dorper rams will briefly be discussed before an overview of the reproductive traits of the Dorper is presented. The management strategies of the Dorpers will concentrate on the age structure of the flock including the age of maiden ewes and the longevity of ewes within the flock. The Dorpers reproductive performance under accelerated mating strategies (mating every 8 months or less) will be discussed as well as comparing these strategies with annual mating systems.

2.1 Reproductive potential of Dorpers

Conception rates

Conception rates of Dorpers seem to be quite consistent at around 90% and compare well to other breeds such as the Merino (Cloete et al., 2000). Conception rates for annual mating of Dorpers have been reported at 89% (Cloete and De Villers, 1987) and 86% (Snyman and Olivier, 2002). In accelerated mating systems (mating every 8 months), results have been similar with 90% (Manyunchi et al., 1991) and 85% (Schoeman and Burger,

1992). However, conception rates in Dorpers have been reported as low as 75% in an accelerated mating system (Schoeman et al., 1993a). In breed studies under accelerated mating conditions, conception rates for the Dorper have been similar to the Merino and Dohne Merino (Basson et al., 1969), tended to be lower than Finnish landrace (Finn) composite breeds (Schoeman et al., 1993a) and similar to the South African Meat Merino (SAMM) (Manyunchi et al., 1991). In Australia, Dorpers have been found to have a 78% higher conception rate than Merinos when both breeds were mated at 8-9 months of age but had similar conception rates when mated at 20 months and older (Kilminster and Greeff, 2011). Overall, the conception rates of Dorpers are generally high and they are similar to many other sheep breeds.

Lambing and weaning percentage

In contrast to conception rates, values for lambing percentage (defined as the number of lambs born per ewe mated) varies in the literature, possibly because of different management systems and nutrition. Table 1 shows the lambing percentages of Dorpers presented in the literature. Schoeman et al. (1993a) showed the lowest results of around 83% lambing of Dorper ewes under accelerated lambing conditions (every 8 months) when fed a pelleted diet, but the ewes were provided with less than half of their energy requirements during lactation (6.3MJ ME/day) which is likely to decrease reproductive rate. Not surprisingly, this was the same study that showed the lowest conception rates in Dorpers so the low lambing percentage may be attributed to this. However, the authors give no reason behind these low reproductive rates of the Dorper, compared to other studies. The highest lambing percentage of Dorper sheep of 157% was also found in an experiment that practiced accelerated mating (Basson et al., 1969). Ewes in this experiment were fed intensively to approximate maintenance requirements on diet of hay, straw and maize meal. The high fecundity of Dorpers in this study shows Dorper ewes have the potential for high reproductive rates, even in accelerated mating systems. In annual systems when ewes grazed natural pasture in South Africa, rates averaged 142% (Cloete and De Villers, 1987; Snyman and Herselman, 2005; Snyman and Olivier, 2002). This is in contrast with a study from Western Australia that showed a rate of 102% (lambs weaned per ewe mated) when ewes were grazing pasture but supplemented to fulfil the maintenance requirements of the Merino ewes in the study (Kilminster, 2010). The reasons behind these differences in fecundity of the Dorper sheep may be associated with nutrition, but this will be discussed in length later in the review. Taking account of all the studies reporting lambing percentage, Dorpers averaged 124% lambs born per ewe mated, but rates reported in the literature are quite variable and depend heavily on nutrition of the ewe.

Because of the variability in lambing percentage reported in the literature, it is only reasonable to compare breeds when managed under the same conditions, as in breed comparison experiments. Dorpers have been shown to have a lower reproductive rate than Finn composite ewes under accelerated mating systems (Schoeman et al., 1993a), but a higher reproductive rate than the Damara under annual mating systems in Australia (Kilminster and Greeff, 2011). Compared to Merino-type breeds, the lambing percentage of the Dorper was not significantly different to South African Mutton Merinos (SAMM) (Manyunchi et al., 1991) and the fecundity of Afrino ewes has been shown to be similar or, under certain extensive conditions, can be higher than that of the Dorper under annual mating (Snyman and Herselman, 2005). When compared to the Dohne Merino, Dorper ewes had a 36% higher fecundity under accelerated mating conditions (Basson et al., 1969). These studies show that the Dorper has a lower fecundity than Finn composite ewes, similar to SAMMs and Afrinos and may have a higher fecundity than Dohne Merinos or Damaras.

The differences in reproductive rates between Merinos and Dorpers are variable and seem to depend on the management system. A study by Snyman and Herselman (2005) compared reproductive traits of Dorpers and Merinos under two different extensive grazing conditions in an annual mating system. On the lower quality pasture type, Dorper ewes had a higher lambing percentage of 140% compared to the Merino at 106%, ($P<0.05$)(lambs born per ewe mated). However, when grazing the better quality pasture there was less difference between breeds with Dorpers having a lambing percentage of 130% compared to the Merinos at 110% ($P>0.05$). This study indicates that with annual mating under extensive grazing conditions Dorpers may have higher reproductive rates than Merinos. This was also found in Australia in young Dorper and Merino ewes when mated annually, but the effect was not seen when the ewes were older (Kilminster and Greeff, 2011). In this study, Dorpers had a higher weaning percentage (lambs weaned per ewe mated) than Merinos when mated at 8 months of age (81% Dorper v 13% Merino) and 20 months age (122% Dorper v 117% Merino)($P<0.05$). However, when mated at 3 years of age, Merinos had a higher weaning percentage than Dorpers (134% vs 105%). The authors suggest the reason for this is that the ewes were fed and managed under optimal conditions for the Merino which was not optimal for the Dorper as it resulted in high lamb mortality in Dorpers (Kilminster and Greeff, 2011). This will be discussed later in the review. When managed under accelerated mating conditions, Basson et al. (1969) found that fecundity of Dorpers was 40% higher than Merinos. This suggests the major reproductive advantage of Dorper ewes over Merinos may lie in the use of accelerated mating systems which will be discussed later in the review. The majority of studies show Dorpers have the capacity for a higher

reproductive rate than Merinos on both annual and accelerated mating systems.

Birth weight and lamb survival

From studies reviewed, the birth weight of Dorper lambs were on average 4.1 kg and the survival rate of lambs from birth until weaning is variable (Table 1). Birth weight of Dorpers is effected by season, age of the ewe, pre-joining body weight, sex and litter size (Schoeman and Burger, 1992). As can be expected, higher birth weights of 5 kg were reported in studies with lower litter sizes (Schoeman et al., 1993b) and slightly lower birth weights were recorded when litter size was high (Snyman and Olivier, 2002). Very low birth weights of 2.8 kg was recorded in a study by Elias et al. (1985) but this seems to be an anomaly as all other studies indicated higher birth weights. Not surprising, this study also recorded low lamb survival rates from birth until weaning at 80%. Other investigators found higher weaning percentages of up to 96% (Snyman and Olivier, 2002). Again, nutrition of the ewe seems to have a major effect as studies demonstrating low lamb survival was shown both when ewes were underfed (Schoeman et al., 1993a) and when ewes were possibly fed too much (Kilminster and Greeff, 2011). Implications of nutrition on reproduction will be discussed in detail later in the review. However, it is clear that in Dorpers, like all sheep, ewe nutrition and environment play a major role in birth weights and lamb survival.

Breed differences in birth weight and lamb survival are small compared to the large influences of nutrition and environment. In comparison with other breeds, Dorper sired lambs tended to be lighter at birth than Dorset lambs, but there was no difference in lamb survival (Notter, 2004). Snowder and Duckett (2003) found no difference in birth weights of lambs from Dorper, Suffolk or Colombia sires, but Schoeman et al. (1995) found that pure Dorper lambs had a higher birth weight (5kg) than lambs from a Finn-composite breed. Snyman and Herselman (2005) found that Merino lambs survived better in one location, but there was no difference in another location. Survival of Dorper lambs between birth and weaning has been shown to be higher than Dohne Merinos but similar to SAMMs in an intensive farming system (Schoeman, 1990). In the sub-humid tropics Red Massai lambs had a much higher survival than Dorper lambs because of their superior resistance to internal parasites. Overall, birth weight and survival of Dorper lambs is reasonably consistent with other breeds and heavily depends on their environment.

Lamb growth until weaning

Dorper lambs can achieve growth rates of around 243g/d from birth until weaning (Table 1). The highest growth rate of 282 g/day (an average of results from two locations) was recorded by Snyman and Herselman (2005) when ewes were mated annually and grazed on natural pasture with no

supplements. The lowest recorded growth rate of 188 g/d was when ewes were also grazing pasture but with supplements under accelerated mating conditions (Manyunchi et al., 1991). Lambs in this study were weaned at 84 days of age and despite being supplemented with creep feed from 3 weeks of age, had low weight gain. However, the authors offer no justification for this (Manyunchi et al., 1991). These results are supported by those of Schoeman et al. (1993b) who weaned Dorper lambs earlier at 62 days and found a growth rate of 190 g/d. It is hard to decipher the reasons for these differences in lamb weight gain between studies because indices such as ewe weights cannot be compared due to lack of consistency of when measurements were taken. Although, lamb growth appears to be independent of mating system since other accelerated mating systems had higher growth rates of around 270 g/d (Schoeman, 1990; Schoeman and Burger, 1992) which suggests other influences, such as ewe condition score. Although ewe nutrition undoubtedly plays a major role in lamb growth rate, there appears to be no clear differences in lamb growth rate from studies where ewes grazed pasture and were un-supplemented compared to those fed a complete diet (Table 1). Type of birth (single or twin) accounted for nearly 20% of the variation in weaning weight in a study by Schoeman and Burger (1992) but as Table 1 shows, the two studies with low pre-weaning growth rates (Schoeman et al., 1993a) also have low lambing percentages which suggests management and nutrition could be the reasons behind varying results. Overall however, Dorper lambs have the potential to grow rapidly from birth until weaning both in intensive and extensive management systems.

Growth rates of Dorper lambs from birth until weaning compare well with other breeds. When grazing on natural pasture in the False Upper Karroo in South Africa, Dorper lambs grew around 100 g/d faster than Merino lambs and around 35 g/d faster than Afrino lambs from birth until weaning (Snyman and Herselman, 2005). Growth rates of the Merino lambs in this study were similar to those recorded in commercial flocks in Western Australia of around 200 g/d (Kelly, 1992) which suggests that under grazing conditions in Australia, growth rates of Dorper lambs would also be higher than Merinos and Afrinos. Pre-weaning growth rates of Dorper lambs was higher than Dohne Merinos or SAMMs under intensive farming systems (Schoeman, 1990). In cross breeding studies conducted in semi-arid Queensland, Dorper sired lambs had a faster growth rate than those sired by Merino, Damaras or Rambuillets, but had similar growth to those sired by Dorsets and SAMMs (Kleemann et al., 2000). In comparison with other hair sheep, St Croix lambs sired by Dorpers grew more rapidly from birth until weaning than purebred St Croix lambs but at a similar rate to pure bred Katahdin lambs (Burke et al., 2003). However, lambs with a higher proportion of Dorper (7/8) grew faster than purebred Katahdin lambs and St Croix lambs (Burke and Apple, 2007). Results from these studies suggest that Dorper lambs have the ability to grow

more rapidly from birth weaning than some wooled breeds such as the Merino and some other hair breeds such as the St Croix.

Dorper rams

Dorper rams reach sexual maturity early so are capable of fertilizing ewes from a young age (Cloete et al., 2000). Spermatogenesis starts at around 63-70 days of age in the Dorper ram and epidermal sperm concentrations rise markedly after 140 days of age (Skinner, 1971). Therefore, outstanding rams could be used discriminately from 140 days of age and intensively from 168 days of age (Skinner, 1971).

Dorper rams are best managed under extensive conditions to maximise fertility. Fourie et al. (2004) found that intensive feeding of young Dorper rams has a detrimental effect on their semen quality as it decreases overall motility and mass motility of sperm. This is likely due to excessive fat deposits on the scrotum with interferes with its ability to thermo regulate. Therefore selection of rams based on scrotal size may be counter-productive if rams are intensively managed and over-fed (Fourie et al., 2004). Due to the Dorper's propensity for disposition of fat, it is important not to over-feed rams or their reproductive potential could be compromised (Fourie et al., 2004).

Table 1: Comparison of pure bred Dorpers and their average reproductive traits over 3 mating seasons or more from different sources. Lambing percentage (lambs born per ewe joined), birth weight of lambs, lamb survival until weaning (lambs weaned/lambs born, number of matings that the data is an average of, mating system (annual or accelerated to every 8 months) and nutrition of pregnant and lactating ewes included in the study.

Average lambing % (lambs born per ewe mated)	Birth weight (kg)	Lamb survival until weaning (%)	Pre-weaning weight gain (g/day)	No of matings included in average	Mating system	Nutrition	Reference
137	2.8	80	-	3	Accelerated	Complete diet	(Elias et al., 1985)
141	4.1	91	273	12	Annual (Dec/Jan)	Natural pasture	(Cloete and De Villers, 1987)
112	4.2	88	188	6	Accelerated	Pasture with supplements	(Manyunchi et al., 1991)
121	4.2	94	270	9	Accelerated	Irrigated pasture	(Schoeman and Burger, 1992)
83	5	-	190	3	Accelerated	Complete pellets	(Schoeman et al., 1993a)(Schoeman et al., 1995
105	4.2	87	269		Accelerated	Complete	(Schoeman, 1990)
150	4.1	96	246	7	Annual (April)	Natural pasture	(Snyman and Olivier, 2002)
135		80	282	3	Annual (April)	Natural pasture	(Snyman and Herselman, 2005)
157		91		4	Accelerated	Intensive complete diet	(Basson et al., 1969)
102 (weaning %)		81%	229 (to slaughter)	3	Annual (Feb/Mar)	Pasture and supplementary feeding	(Kilminster, 2010) (Australian study)
Average across all studies							
124%	4.1	87.5%	243				

In conclusion, Dorpers have the ability for high reproductive performance under the right management conditions. Compared to other hair breeds, Dorpers tend to perform better than St Criox and Damara breeds but similar to Katahdins (Burke and Apple, 2007; Kilminster and Greeff, 2011; Kleemann et al., 2000). However, Dorpers have a lower litter size than highly fecund breeds such as the Finn (Schoeman et al., 1993a). The majority of studies show that Dorpers have the capacity to produce more lambs than wooled breeds such as the Merino and Dohne Merino, especially under accelerated mating conditions (Basson et al., 1969; Schoeman, 1990; Snyman and Herselman, 2005). However, to reach their production potential, the Dorper flock must be managed in a way that optimises their reproductive success. These management strategies will now be discussed.

2.2 Management strategies of Dorpers

The age structure of the flock and the mating system that is implemented are very important aspects of sheep management. Farmers need to know what age young ewes can be introduced into the breeding flock, what age the ewes reach their reproductive peak and at what age they are no longer productive and should be culled. As well as the age structure of the flock, the mating strategy used is also important and can differ between breeds. This is particularly important in the Dorper because they can be mated under an annual or accelerated mating system. This section will discuss the age structure of the Dorper flock and then investigate the performance of Dorpers under accelerated mating conditions and how this compares to the annual mating systems that are normally used in Merino sheep flocks in Australia.

Maiden ewes

Dorpers are an early maturing breed so ewes can be mated at around 8 months of age. A study by Greeff et al. (1988) found that Dorper ewes have their first oestrus at around 6 months of age if they weigh above 43kg. Data from a study by Schoeman et al. (1993a) shows the onset of puberty in Dorper ewes a little later at 8 months of age when they weighed 50kg and had an ovulation rate of 1.13. Table 2 shows the reproductive data from maiden Dorper ewes in different studies. This shows that Dorpers can be successfully mated as early as 7 months of age. However, many studies have only incorporated maiden ewes into the breeding flock once they have reached 40 kg (Schoeman, 1990; Schoeman and Burger, 1992; Snyman and Olivier, 2002). Therefore, it is recommended that maiden ewes can be mated as early as 7 months of age provided they weigh at least 40 kg.

Table 2: Age of maiden Dorper ewes when they were first mated, their weights and lambing percentages.

Age at mating (months)	Weight at mating	Lambs born/ewe mated	Lambs weaned per ewe mated	Reference
7	40	77 %	63%	(Snyman and Olivier, 2002) (data from hair Dorpers)
7	43	114%		(Greeff et al., 1988)
9	42	86%	81%	(Kilminster and Greeff, 2011) (Australian study)
8	50	83%		(Schoeman et al., 1993a)
13		122%		(Elias et al., 1985)
19		112%	99%	(Manyunchi et al., 1991)

Because Dorpers mature early, maiden ewes can be incorporated into the breeding flock earlier than in some other breeds. When Merinos were mated at 8 months of age, their lambing percentage was 13% compared to the 9 month old Dorpers who had a lambing percentage of 86% in Western Australia (Kilminster and Greeff, 2011). Maiden Dorper ewes lambed 3 months earlier than maiden SAMMs and 4 months earlier than maiden Dohne Merinos when exposed to rams from 11 months of age (Schoeman, 1990). Dorpers also reach puberty sooner than Romanov ewes (Greeff et al., 1988), but the onset of puberty is similar for Dorpers and Finn composite ewes (Schoeman et al., 1993a). Earlier sexual maturity than wooled breeds such as the Merino gives the Dorper an advantage in production systems because it allows an extra years mating for the same age group of ewes.

Productivity of adult ewes of different age groups

It is important for producers to know at what age ewes reach their reproductive peak and the longevity of the ewes. Schoeman and Burger (1992) showed that litter size of Dorper ewes peaked at around 5 years of age to a value of 1.58 lambs born per ewe lambing and that this age group had the highest weaning weights of lambs. Fertility of Dorper ewes reached their peak of 94% conception rate at 4 years of age, but even at 7 years of age ewes still had a good fertility of 82% conception, litter size of 1.39 and the highest total lamb weight at 100 days of any age group. Similarly, data from Cloete and De Villers (1987) shows that Dorper ewes 7 years or older still had a weaning percentage of 134% (lambs weaned per ewe mated) which was not different from the younger age groups. Similarly Basson et al. (1969) found no decline in reproduction in Dorper ewes at 7-8 years of age even when under an intensive accelerated mating system. However in contrast, one study showed that Dorper sheep should be culled at 5 years of age and were not retained in the flock as long as SAMM ewes (Manyunchi et al., 1991). Manyunchi et al. (1991) found that although Dorper ewes were 10-12% more productive per season than SAMM ewes, SAMM ewes had a superior longevity than Dorper ewes and were retained in the

flock for one extra season which resulted in a 28% higher lifetime production compared to Dorpers. In this study, ewes were culled if they either failed to rear a lamb in two consecutive seasons or had lost their permanent incisors. Since the other studies have shown that Dorpers can still reproduce efficiently until 7 years or older (Basson et al., 1969; Cloete and De Villers, 1987; Schoeman and Burger, 1992), it is possible that the grassland diet of the Dorper ewes in this experiment caused them to lose their incisors and be culled. Overall, the majority of studies show that Dorper ewes are able to maintain high reproduction rates until 7 years of age or older.

Mating strategies: accelerated and annual mating

In South Africa, Dorpers are used in both annual and accelerated mating systems (every 8 months). As Table 1 shows, generally an accelerated mating system was used in intensive studies where ewes were fed pellets, but in more extensive situations where ewes grazed natural pasture, an annual mating system was often used. It is unclear why an annual mating system is generally used when Dorpers grazed native pasture in South Africa. It may be due to ease of management in extensive farming systems where sheep need to be mustered over large distances or that the poor quality of the native pasture does not provide enough nutrition for accelerated mating systems, however there is no published data to support this. These systems in South Africa may are similar to the rangeland farming systems in Australia where grazing distances are vast and forage quality low. Therefore an annual mating system of Dorpers may be appropriate in these pastoral regions of Australia as well. In southern Australia where the majority of sheep are produced, most ewes are mated annually in summer/Autumn which is the natural breeding season for the Merino. One of the main advantages that Australian producers see in Dorpers is that their breeding is not as seasonal as Merinos so they can be mated every 8 months in accelerated systems. Some Dorper producers in Australia are even mating their ewes every 6 months (Bird, A., personal communication). As well as producing more lambs per year, this also allows production of out-of season lambs which usually fetch a higher price due to low supply, however this may be off-set by a higher cost of production when pasture availability is low. The ability of Dorpers to perform under accelerated mating systems will now be discussed as well as how Australian producers may be able to best manage reproduction in Dorpers depending on their farming system.

The Dorper performs well under accelerated mating systems compared to other breeds. Schoeman (1990) compared the productivity of Dorper, Dohne merino and SAMM ewes under accelerated mating conditions where ewes were exposed to rams at 4 month intervals. Under this system, the total output of lambs per ewe per year was higher in the Dorper (35.1kg of total lamb live weight at weaning) compared to the SAMM (29.7kg) and the Dohne Merino (26 kg). Output per metabolic weight of the ewe was also higher in the Dorper. This agrees with work from Basson et al. (1969) who showed that Dorper ewes produce more lambs than Dohne Merinos and

Merinos under an accelerated mating system (2.36 lambs per ewe per year for the Dorper, 1.82 Dohne Merino and 1.77 Merino). However, Finn composite ewes can produce more lambs than the Dorper under accelerated mating conditions (1.2 lambs per ewe per year for the Dorper compared to 2 for Finn composite ewes) (Schoeman et al., 1993a). Dorper ewes can produce more lambs than Merino and Merino-type sheep under accelerated mating conditions.

Table 3: Accelerated mating of Dorper ewes in different studies showing months in which ewes were mated, duration of joining and reproductive rate per year (lambs born per ewe mated per year).

Months mated	**Duration of ram exposure**	**Reproductive rate per year**	**Reference**
Jan/Feb May/June Sept/Oct	1 month	1.46	(Schoeman, 1990)
March/April Nov/Dec July/Aug		2.36	(Basson et al., 1969)
May/June Sept/Oct Jan/Feb	1 month. Rams exposed to ewes every 4 months	1.21	(Schoeman and Burger, 1992)
April/May Nov/Dec July/Aug	5 weeks	2.06	(Elias et al., 1985)
(8-9months) Mach/April Dec/Jan Aug/Sept May/June	35 days	1.17	(Manyunchi et al., 1991)
April/May Dec/Jan Aug/Sept		1.24	(Schoeman et al., 1993a)

Although Dorpers are thought to be unseasonal breeders, there is evidence that conception rates increase during the natural breeding season for sheep. Even though the Dorper is acknowledged for its prolonged breeding season, some studies have shown a very pronounced increase in both fertility and fecundity of ewes mated in Autumn (Joubert, 1972). Other studies agree and found that oestrus activity of Dorpers was higher when joined in May/June compared to Sept/Oct or Jan/Feb (Schoeman, 1990; Schoeman and Burger, 1992). When the duration of post-partum anoestrus was studied, ewes lambing in autumn returned to oestrus 62 day post-partum whereas when ewes lambed in spring and winter it took around 123 days to return to oestrus and this effect was independent of nutrition of the ewes (Joubert, 1972). In contrast, Elias et al. (1985) found no seasonal limitations to the reproductive cycle of the Dorper and called Dorpers a “breeding factory”. This

agrees with other studies (Basson et al., 1969). These results suggest that although Dorpers may be much less seasonal in their breeding habits than other breeds such as the Merino, there still may be elements of seasonality to their mating cycle. Farmers may be able to increase reproductive rates by ensuring that time of mating best incorporates this possible seasonal effect.

It is unknown whether this seasonal effect occurs in Australia and if it does, what are the best times to mate ewes. South Africa is at similar latitude to the southern livestock production areas of Australia so photoperiods would be similar. However, other factors to consider in Australian systems are feed availability and the need to match maximum nutrient requirements of the ewe to maximum feed availability. Also, capitalising on high out-of season lamb prices may increase profitability for the farmer, depending on feed costs. A suggestion for the possible mating and lambing times of Dorper ewes in southern Australia is shown in Table 4. Other things to consider, particularly in a mixed crop/livestock production system, are how lambing fits around other farm activities such as seeding and harvest. Optimal time of mating may differ depending on farming regions, farming systems and priorities of individual farmers.

Table 4: Suggestion for reproductive schedule of the mating of Dorper ewes in southern Australia

Mate	**Lamb**	**Comments**
May	October	Utilises increased fertility in Autumn and increased feed available for ewes in spring lambing.
January	June	Normal breeding season for sheep in Australia.
September	February	Utilise possible decreased duration of post-partum anoestrus in Autumn. Capitalise on out-of-season lamb market. Disadvantage is low pasture availably for ewes and possible heat stress during lactation in some climates.

Flexibility in mating seasons is a major advantage that Dorpers have over other breeds such as the Merino in Australia, but some studies suggest that in extensive farming systems there are few benefits to accelerated mating over annual mating. Schoeman and Burger (1992) tested the performance of the Dorper under accelerated mating conditions where ewes were exposed to Dorper rams for one month at 4 month intervals over 4 years. Ewes were fed on irrigated and dry-land pasture and were fed concentrates when body condition score was 2 to 2.5. The authors found that the number of lambings per ewe joined per year was only 105%. They concluded than this was not a satisfactory improvement on the theoretical maximum of 100% for traditional annual mating. The number of lambs born per ewe joined per year was 1.21 in this experiment which, as Table 1 shows, is less than other studies where ewes were mated annually (Cloete and De Villers, 1987; Snyman and Herselman, 2005; Snyman and Olivier, 2002). A lower ewe productivity for accelerated mating compared to annual mating was also seen in other ewe breeds such as Finn, Rambouillet, Dorset, Targee and Suffolk (Fogarty et al., 1984).

As Schoeman and Burger (1992) state, extra ewe outputs require extra ewe inputs therefore using an accelerated mating system with Dorpers may only have production advantages over annual systems if farmers are prepared to provide ewes with optimum nutrition and management. Therefore, Dorpers will only reach the high reproductive potential they are capable of if their nutrition and management are optimised.

In summary, Dorpers have the potential to perform well under accelerated mating conditions compared to other Merino-type breeds. Although Dorpers are thought to be unseasonal in their breeding, increases in fertility, fecundity and an earlier return to oestrus after lambing during their natural breeding season of Autumn suggest some seasonality. Accelerated mating may have benefits over annual mating if farmers are prepared to intensify their management of Dorpers and can cost-effectively provide additional nutrition to ewes in order to produce more lambs. Since accelerated mating is one of the main advantages the Dorper has over traditional breeds such as the Merino, it is very important to maximise lamb production using this system.

2.3 Overall reproductive potential of the Dorper

The low sheep numbers in Australia and high demand for sheep meat make it imperative that the high reproductive potential of the Dorper is reached in Australia. It is possible to estimate the potential production of the ewe over her lifetime using the reproductive data that has been presented so far in this review (see Tables 1-4 for summaries). Table 5 collates this data to show the production potential of the Dorper using data from an accelerated mating system in South Africa (Basson et al., 1969) compared to an annual mating system in Australia for the Merino (Kilminster and Greeff, 2011). Data on weaning weight in these studies were not available so data on weaning weights of Dorpers and Merinos under the same extensive grazing system in South Africa was used. These numbers are theoretical and must be viewed conservatively, they are using high lambing percentages for both breeds which may not be indicative of the average flock, they also don't take into account a lower lambing percentage for maiden ewes and the wool production of the Merino is not accounted for. However, it terms of lamb production potential, it does illustrate that mating Dorpers under accelerated conditions could have the potential to produce over twice the number of lambs per ewe lifetime than Merinos mated annually which is the typical mating system in Australia. It also shows that Dorpers have the potential to produce nearly 3.5 times more kilograms of total lamb live weight than Merino ewes over their lifetime. These production rates of Dorpers are yet to be proven under Australian conditions but they do indicate the much higher sheep meat production potential of the Dorper ewe, over the Merino ewe per ewe lifetime.

Table 5: The theoretical potential lamb production of Dorper and Merino ewes per ewe lifetime using data from reproductive studies (Basson et al., 1969; Greeff et al., 1988; Kilminster and Greeff, 2011). Since data on weaning weights were not included in these reproductive studies, lamb weaning weights from Snyman and Herselman (2005) were used which is an average over 2 locations in extensive grazing systems in South Africa. Data on age at weaning was not given.

	Dorper	**Merino**
Age at first lambing	8 months	18 months
Avg number of lambs per ewe mated per mating	1.57	1.25
Frequency of mating	8 months	1 year
Years in flock	6	6
Total number of matings per ewe lifetime	8	4
Total number of lambs produced per ewe lifetime	12	5
Average weight per lamb at weaning (kg)	30.8	21.7
Total kg of lamb produced per ewe lifetime	370	108

This theoretical high level of lamb production is one of the main attributes of the Dorper that appeals to producers, but turning theoretical lamb production into actual number of lambs on the ground may prove to be more difficult. No reproductive statistics on commercial Dorper flocks in Australia have been published, whereas for Merinos, even though their reproductive potential might be 125%, the average lambing percentage recorded (lambs born per ewe mated) for Merino ewes in Australia is only 75% (Moir, 2002). Thus, there is often a large difference between the reproductive potential of a ewe and the reproduction rates they achieve in commercial flock situations. High production systems require high inputs which is not necessarily the most economically viable production system for the farmer when feed costs are high. Therefore, it is essential for the profitability of the livestock enterprise to make the most efficient use of the feed resources available so that the highest reproductive rates can be achieved on the most economical amount of inputs. Thus, the ability of producers to achieve the high reproductive potential of Dorpers hinges on their knowledge of nutrition and the economics of suppling that nutrition to the ewe year-round.

3. Nutrition during reproduction

Optimising the nutrition of the Dorper ewe is the key to economically achieving the reproductive potential of the breed. Although the Dorper's basic nutritional requirements are undoubtedly similar to other breeds of sheep, the fine-tuning of these requirements under different management systems and different phases in the reproductive cycle determines the profitability of the sheep enterprise. The majority of sheep in Australia are managed under extensive conditions, some in harsh

environments where providing all the ewes nutritional requirements at all times are simply not economical. Under these systems, targeted nutrition at specific times in the reproductive cycle is the most effective strategy. The optimal nutritional strategy has been determined for the Merino in Australia (Young et al., 2011), but it has not been verified for the Dorper. The critical periods of reproduction in sheep that most influence production levels are joining as well as late pregnancy and early lactation. In this section of the review, nutrition of the ewe during these critical phases of reproduction will be discussed. Incorporated into this will be an evaluation on whether the current recommendations for Merinos should also be applied to Dorpers and the breed differences that may mean Dorper ewes need to be treated differently than Merinos. First however, the influence of nutrition on the duration of post-partum anoestrus of Dorper ewes will be discussed as this is particularly important in accelerated mating systems.

3.1 Nutritional influences on post-partum anoestrus

Shortening the period of time it takes for Dorper ewes to return to oestrus after lactation is crucial for accelerated mating systems. Although there is limited information available on this, studies have found that although Dorpers are thought to be unseasonal breeders, there is an element of seasonality in their reproduction (Basson et al., 1969; Joubert, 1972). Joubert (1972) found that ewes mated in Autumn had higher fertility and fecundity (113%) than those mated during winter, spring or summer (range 78-85%). Ewes that lambed in spring and winter returned to oestrus around 123 days post-partum and those than lambed in summer returned 88 days post-partum. Due to the influence of breeding season, autumn lambing ewes returned to oestrus much sooner at 61 days post-partum. The effect of nutrition was also examined in this paper with ewes fed either on a high level of nutrition (maintenance) or a low level which was only 40% of maintenance from birth until weaning at 100 days After weaning of lambs , all ewes returned to high nutritional level. Level of nutrition did not influence the duration of post-partum anoestrus in any of the seasons except summer. However, the long term effects of this sort of severe feed restriction are unknown. Data from Basson et al. (1969) agrees with these results and also found the duration of post-partum anoestrus of Dorper ewes shorter during Autumn (51 days, March/April) than during winter (81 days July/August) or spring/summer (74 days, Nov/Dec). The authors state that despite the high plane of nutrition, there was still a seasonal effect and surmised that nutrition is also likely to play a large role in duration of post-partum anoestrus. Duration of post-partum anoestrus in Dorper ewes seems to be influenced by season, and possibly nutrition, with the shortest time during the natural breeding season of Autumn.

3.2 Nutrition during the joining period

There is very limited information on the effect of nutrition during the joining period in Dorper ewes. Only one study has been found that manipulated Dorper ewe nutrition at joining to increase production. Basson et al. (1969) fed Dorper, Merino and Dohne Merino ewes maintenance rations during 3 weeks of mating in their second breeding season and then in their third and fourth seasons they were on a high feeding level during mating (around 15 MJ of estimated net energy intake per day). Comparing the second breeding season to the fourth shows that weaning percentage of Dorpers increased by 20%, Merinos increased by 15% and Dohne Merinos increased by 5%, but it is unclear whether these increases are significant or if there are significant between breed differences. It is likely that the fertility of Dorper ewes is responsive to nutrition during the joining period as it is in other breeds, but there is limited information available.

Even though there is little information available on whether targeted nutrition during the joining period influences fertility of Dorper ewes, measuring the condition score of ewes at joining and their subsequent reproductive rate can give clues as to whether nutrition plays a role. Two studies have been found that investigated the influence of pre-joining body weight of Dorpers on reproductive traits, but some of the results are conflicting. Schoeman and Burger (1992) found that pre-joining body weight did not significantly influence conception rates or litter size at lambing, but heavier ewes at mating tended to produce heavier lambs at 100 days old. Cloete and De Villers (1987) also found that mating live weight did not influence conception rates, but in contrast to the previous study, higher pre-joining body weight linearly increased the rate of multiple births ($P<0.05$). This effect was especially pronounced with young ewes at 2 years of age. The positive influence that a high body weight and plane of nutrition of ewes has on ovulation rate has been well documented in other breeds of sheep such as Merinos, Corriedales and Scottish blackface (Gunn et al., 1969; Nottle et al., 1997; Viñoles et al., 2009). Therefore, it is likely that in Dorpers with a high pre-joining body weight, ovulation rate is increased, but conflicting results indicate more work needs to be done to clarify this relationship.

It is common practice in Merino flocks in Australia to feed lupins prior to and during joining in increase ovulation rate, but it is unknown whether this tactic would be effective with Dorpers since there are breed differences to this response. In Merino ewes, feeding 500 grams per head per day of lupins for 14 days prior to and during joining increases the fecundity of ewes and results in a 15% increase in lambs born per ewe mated (Nottle et al., 1997). Similarly, providing a supplement of corn grain and soybean meal to Corriedale ewes for 7 days increased ovulation rate by 14% (Viñoles et al., 2009). However, breed of ewe seems to influence this response and also interacts with the previous condition score of the ewe. In Merino ewes, increased ovulation in response to lupin supplementation has been shown regardless of body condition (Pearse et al., 1994). Whereas in Scottish Blackface sheep,

increasing feeding level had no effect on ovulation rate in moderately fat ewes (condition score 3), but increased ovulation rate in lean ewes (condition score 1.5) (Gunn et al., 1969). Lassoued et al. (2004) found that the response of ovulation rate to level of nutrition is influenced by the breed of sheep as improved nutrition increased ovulation rate in the prolific D'Man breed but there was no difference in ovulation rate of Queue Fine de l'Quest ewes that have lower fertility. There is no literature investigating the ovulation response of Dorper ewes to body condition and plane of nutrition and, as there is a possibility of breed differences, it is hard to extrapolate data from other breeds.

3.3 Nutrition during late pregnancy and lactation

Regardless of breed of sheep, nutrition during late pregnancy and early lactation is of the utmost importance for the survival of the ewe, her lamb and even the future productivity of the lamb. The nutritional requirements for sheep during reproduction is well documented (SCARM, 1990) but in commercial flock situations, sheep often consume less than their requirements due to a lack of quality and quantity of food, particularly during late pregnancy and lactation when their feed requirements are highest. It is extremely important for the profitability of the livestock enterprise to make the most efficient use of the feed resources available. Therefore, the nutrition of the ewe needs to be optimised so that she is fed enough to reach her reproductive potential, but not so much as to be uneconomical to the farmer as cost of feed and stocking rate also major determinates of profitability. This section will first discuss the information available on the nutrition of Dorper ewes during late pregnancy and lactation, and then discuss to what level the current recommendations for the nutrition of Merino ewes in Australia apply to Dorper ewes. The reproductive efficiency of the Dorper ewe will then be discussed.

Unfortunately there is very limited information of the nutrition of the Dorper ewe during the critical times of late pregnancy and early lactation. There have been no studies that manipulate nutrition during this period to evaluate the effects on the ewe and her lamb. Table 6 lists the reproductive studies conducted on Dorpers, the type diet they consumed and their reproductive rates. References have been listed in decreasing order of reproductive rates. Generally, there is little information given on the diets of the ewes in these experiments and when the ewes were grazing natural pasture, no indication of herbage quality is included in the paper. Similarly, body condition score was rarely included but one study indicated that ewes were supplemented if they were less than 2-2.5 in condition score (Schoeman and Burger, 1992). Much more information is needed before the optimal nutritional regime for Dorper ewes during late pregnancy and lactation can be determined.

Table 6: A list of studies that contain data on reproduction of Dorpers and the information provided about the diet of the ewes in the study and the mating system used (annual or accelerated- every 8 months). Lambing percentage refers to number of lambs born per ewe mated. Additional information on references is shown in Table 1.

Lambing %	Mating system	Nutritional information available from paper	Reference
157	Accelerated	During late pregnancy estimated net energy intake was 7.7 MJ/day when fed *ad lib* lucerne hay, maize meal and oat straw. During early lactation estimated energy intake was 14 MJ/day (data conversions made)	(Basson et al., 1969)
150	Annual	Natural pasture, no minerals or supplements provided. Experiment conducted north-western Karoo South Africa, 209mm annual rainfall.	(Snyman and Olivier, 2002)
141	Annual	Natural pasture near Lambert Bay South Africa, receives 152mm annual rainfall. No indication of supplementation of ewes.	(Cloete and De Villers, 1987)
137	Accelerated	Lactation diet of 2.5 kg alfalfa hay and 1 kg concentrated containing 16% protein, 2 % fat, fibre 7.5%	(Elias et al., 1985)
121	Accelerated	Irrigated pasture and cultivated dryland pasture and natural pasture. Ewes were only supplementary fed when average body condition score was 2 to 2.5.	(Schoeman and Burger, 1992)
112	Accelerated	Natural pasture plus 500g/h/d maize meal during late pregnancy. During lactation ewes received pasture plus a 750g/h/d of supplement consisting of 90% maize meal and 10% protein concentrate.	(Manyunchi et al., 1991)
102 (weaning %)	Annual	Grazed pasture and supplementary fed to optimal nutrition for the Merino which is maintenance of body condition score 3 of the Merino sheep in the study.	(Kilminster and Greeff, 2011) (Australian study)
83	Accelerated	Pellets 0.6kg at 10.5 MJ ME/Kg DM, 10% CP DM. This equates to 6.3 MJ ME/day.	(Schoeman et al., 1993a)
Data not given		Grazed natural pasture, different rates of supplements were fed. No energy data. Over two seasons, digestible organic matter intake during early lactation over two seasons ranged from 703 g/day to 1029 g/day. Crude protein ranged from 107 g/d to 175 g/day.	(De Waal and Biel, 1989b)

The variation in the reproductive rates in these studies can be mainly attributed to nutrition and management of the ewes. In many reproductive studies done on Dorpers, ewes were fed below their maintenance requirements, but production levels

may also be influenced by mating strategy. In the study with the highest reproductive rate, ewes were under accelerated mating conditions and when fed *ad lib* consumed around 14 MJ of energy per head per day which slightly less than their requirements of around 16 MJ (Basson et al., 1969). However, in accelerated systems where ewes were provided with less than half of their requirements (6.3 MJ/day) reproductive rate was much lower at 83% (Schoeman et al., 1993a) which is to be expected. However, two out of the top three lambing percentages were when ewes had presumably the lowest quality diet out of all the studies as they were grazing arid pastures and scrub with no supplements provided (Cloete and De Villers, 1987; Snyman and Olivier, 2002). In these two studies, ewes were mated annually but, even so, to produce 150% lambing in arid conditions with no supplementation indicates that the Dorper ewe is very resilient to harsh conditions. In contrast, in Australia when ewes were fed at Merino nutrient requirement levels and mated annually their weaning percentage was low (102%) (Kilminster and Greeff, 2011). This suggests that higher feeding rates do not always equate to higher reproductive rates in the Dorper when mated annually. Overall, Dorper ewes seems to respond well to good nutrition under accelerated mating conditions but also cope well under harsh nutritional conditions when mated annually.

Since there is very little information available on nutrition during late pregnancy and early lactation which is specific to Dorper ewes, it may be appropriate to apply the knowledge of the best practice systems in other sheep breeds. Since the Merino is the most common sheep breed in Australia, it is useful to investigate how the current recommendations for Merinos in Australia might apply to Dorpers.

3.4 Applying recommendations for Merinos ewes to Dorpers ewes

In Australia, the “lifetime wool” project has optimised the nutrition of the Merino ewe and showed considerable productivity gains can be achieved when the ewe is maintained in condition score 3 throughout pregnancy and lactation (Young et al., 2011). It is easy to assume that optimum nutrition for the Merino ewe will be the same for the Dorper ewe, but this may not be the case. Even between different strains of Merinos such as the South African Mutton Merino and the Merino there are differences in the way ewes partition nutrients during late pregnancy and early lactation (Brand and Franck, 2000). Therefore, it stands to reason that there would be differences between hair sheep such as the Dorper and wool sheep like the Merino. This section investigates if the current best practice strategy for Merino ewes can also be applied to Dorper ewes and how the breeds may differ.

Appling the “lifetime wool” principles of Merino nutrition to Dorper sheep may be detrimental to their reproductive performance when mated annually. In the low rainfall wheatbelt of Western Australia, Kilminster and Greeff (2011) fed Merino, Dorper and Damara ewes according the principles of Lifetime Ewe Management (Trompf et al., 2008). The ewes grazed together and were managed so that the

Merino ewes were maintained in condition score 3. When food on offer was lower than maintenance requirements for the Merino ewes, all sheep were supplementary fed. At their first joining at 9 months of age, the condition score of the Damaras was 2.3, Dorpers 2.4 and Merinos 1.8. Maiden Dorper ewes achieved 86% lambing (lambs born per ewe mated) and maiden Damara ewes achieved 71%, much higher than Merinos at 13%. There were no lamb losses between birth and weaning in the maiden Damara ewes and maiden Dorper ewes lost only 5% of their lambs until weaning. By the second joining, 12 months later, both Merinos and Dorpers had increased body condition by 1 condition score so that Merinos were 2.8, Dorpers were 3.3 and Damaras had gone up to 2.8. Although the lambing percentage of Dorpers was high (145%), 23% of the lambs born to Dorpers died before weaning. This result was again repeated the following year with 137% lambs born per ewe mated but with 27% of those lambs dying before weaning. This unacceptably high rate of reproductive wastage was attributed by the authors to a change in the maternal behaviour as the Dorper ewes showed little interest in their lambs which caused them to abandon their lambs (Kilminster and Greeff, 2011). Despite being fed the same diet the Dorpers in this study were increasing in condition while Merino ewes were maintaining condition (Kilminster, 2010). Birth weights were not measured in this experiment but since the ewes were gaining condition it is possible that Dorper lambs became too large which caused birthing difficulties and resulted in low lamb survival (Kelly, 1987). Similarly, the Damaras in the study also became over-fat when on this feeding regime and after lambing at 71% at 9 months of age, decreased to 52% and 64% in subsequent years. The authors attributed this to the over-fat tails becoming a physical impediment to mating. From this study it is clear that when the optimal nutritional management practices for the Merino in Australia are applied to arid hair breeds such as the Dorper and Damara, their reproductive efficiency is compromised. Therefore, we need to establish why the Dorper may be different from the Merino in its reproductive requirements.

As well as producing a lamb, Merino ewes must also partition their nutrients towards wool growth whereas Dorper ewes only need to partition nutrients to their lamb. As its name suggests, the main focus of the “lifetime wool” project was to provide nutritional recommendations that would optimise the wool production of the ewe and her lamb. Fluctuations in nutrition of Merino ewes lead to lower staple strength of the wool which is a major determinant of value of the wool clip. Therefore, it is beneficial to both the quality and quantity of wool that Merino ewes maintain their condition during reproduction so wool growth and quality is not compromised. However, in hair sheep there is no wool to produce so Dorper ewes can partition a larger proportion of the available nutrients to reproductive traits such as milk production, which is why Dorper lambs grow more rapidly than Merino lambs (De Waal and Biel, 1989a; Snyman and Herselman, 2005). These differences in nutrient portioning are also seen between different types of Merinos with South African Mutton Merinos having a higher milk production and growth of their lambs compared to the Merinos who have a higher wool production (Brand and Franck, 2000). Fluctuations in the body

condition of Dorper ewes may have less of an economic impact to the farmer than in Merino ewes because there is no wool production to consider.

Another major difference between Merinos and Dorpers which can influence their reproductive requirements are breed differences in the deposition and utilisation of body reserves. De Waal and Biel (1989a) found that when grazing low quality pasture with some supplements, Dorper ewes utilised more body reserves during pregnancy and lactation than Merino ewes. During lactation, Dorper ewes lost 100% more live weight than Merino ewes, but their lambs gained weight 100% faster than Merino ewes. This suggests that Dorper ewes were able to mobilise more of their body tissue towards milk production to sustain higher growth rates for their lambs. Data from Basson et al. (1969) agrees with this theory. They fed Merino and Dorper ewes an *ad lib* diet of lucerne hay, maize meal and oaten straw during three 8 month long reproductive cycles. Figure 3 shows the change in live weight of ewes from their live weight at early pregnancy. No data on variation is given in this study so it cannot be ascertained whether differences are significant. However, numerically, the Dorper ewes utilised 250% more body reserves from early pregnancy to early lactation. Part of this difference is because Dorper ewes had a 39% higher lambing percentage than Merinos so their nutrient requirements would have been higher. But, rather than increasing their energy intake to compensate for this, they utilised their body reserves to a much greater extent than Merinos. A major reason for this is appears to be that Dorper ewes are generally heavier than Merino ewes so they have more body reserves to utilise during reproduction. But, it could also be due to differences in nutrient partitioning whereby the physiology of Dorper ewes allows more body reserves of the ewe to be sacrificed so that milk production is not compromised when energy intake is limited. The Dorper ewe seems to have a better capacity to utilise its more abundant body reserves during the period of peak nutritional demand than the Merino.

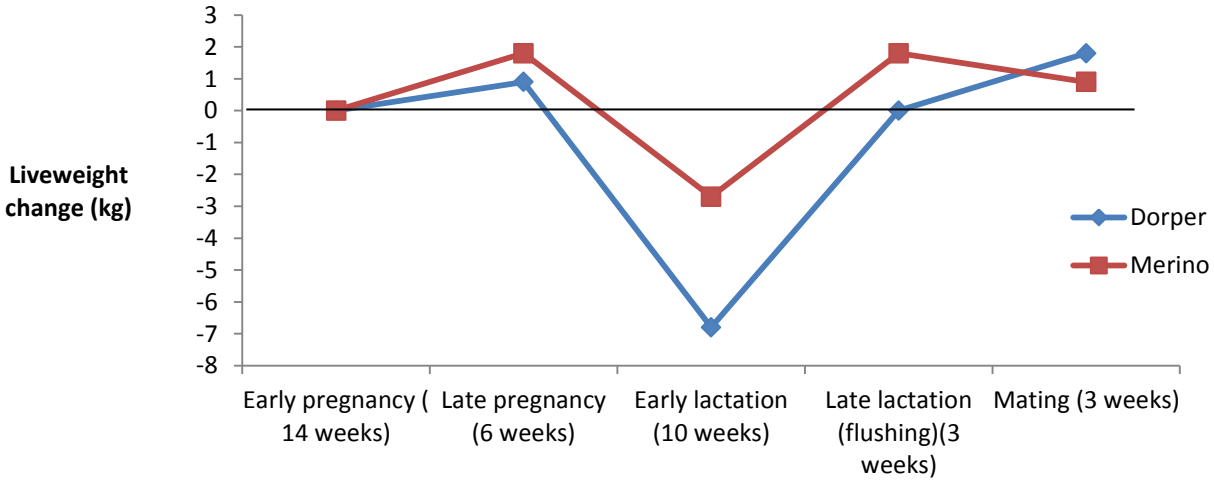

Figure 3: Change in live weight (kg) from early pregnancy in Dorper and Merino ewes over an 8 month reproductive period when fed *ad lib* ration on lucerne hay, maize meal and oat straw. The number of weeks in brackets indicates the length of time the data points are an average of since the graph it not to scale. Data adapted from Basson et al. (1969).

The ability of the Dorper to utilise its body reserves may help to buffer their lambs against inadequacies in nutrition of the ewe. Joubert (1972) fed Dorper ewes on a high level of nutrition (0.1kg digestible protein and 1.2kg TDN (total digestible nutrients) per day, equivalent to 18 MJ ME) or low nutrition (0.05kg digestible protein and 0.5KG of TDN per day or 7.5 MJ ME) for two mating seasons from the start of lactation until lambs were weaned at 100 days. As expected, ewes on the low level of nutrition lost more weight during lactation than those on the high plane of nutrition. However, even with a 60% decrease in their energy intake there was no decrease in the weaning weight of the lambs from the low nutritional group, with the exception of one breeding season. This experiment was only performed over four mating seasons, so long term effects of low nutrition during lactation on ewe and lamb performance cannot been seen, but it does illustrate the Dorpers ability to readily utilise body reserves to replace a 60% reduction in energy intake with little impact on weaning weight of lambs. In contrast, the growth rates of Merino lambs until weaning appear to be much more sensitive to the nutrition of the ewe during lactation. The amount of feed on offer for grazing Merino ewes has a large impact on the growth rate of lambs until weaning because as feed on offer increases, so do lamb growth rates, to a point (Thompson et al., 2011). This indicates that in the Merino, milk production fluctuates with energy intake whereas in the Dorper, the lamb is buffered from fluctuations in energy intake by the ewe utilising her body reserves to compensate when there is a deficit in energy intake. Milk production in the Dorper ewe seems much less sensitive to changes in energy intake because of their ability to utilize their more abundant body reserves.

Breed differences may also be apparent in the metabolic requirements of Dorper and Merino ewes during pregnancy and lactation. De Waal and Biel (1989b) found that when grazing pasture with some supplements, Merino ewes had a higher herbage intake per metabolic size than Dorper ewes (digestible organic matter intake/live weight (kg) $^{0.75}$ /day). Both breeds consumed similar amounts of herbage, but Dorper ewes were 22-28% heavier than Merino ewes. However, these differences were not apparent in a study by Basson et al. (1969) who fed ewes a more concentrated diet of diet of lucerne hay, maize and oat straw *ad lib*. With some adaption of the data (unit conversions), Figure 4 shows the daily estimated net energy (ENE) intake of ewes per metabolic weight (live weight kg $^{0.75}$, live weight includes conceptus weight during pregnancy). Numerically, energy intake per metabolic weight seems to be similar between breeds until late lactation when Dorpers seem to have an increased intake. However, the intake of lambs was also included in this data and since Dorpers had a higher number of lambs the lambs would have consumed more resulting in higher total intake. Dorper ewes weaned on average 38% more lambs than Merinos which equates to an extra 7.5kg of weaned lamb live weight per ewe. Figure 5 accounts for this increased production by showing the same data as Figure 4 but divided by the average weaning weight of the lambs produced per ewe. Visually, it appears that Merino ewes require more energy per metabolic weight to produce one kg of lamb than Dorper ewes. This stands to reason as rearing twins is

more efficient than rearing singles (Fogarty, 1984) and Dorpers had a higher number of twins. The notion that Dorpers have lower metabolic requirements than Merinos when consuming low quality foods (as seen in the data by De Waal and Biel (1989a)), but not when on higher quality foods (as in the case of Basson et al. (1969)) will be discussed at length in the adaptation section of the review. It is unlikely that the metabolic requirements during late pregnancy and lactation in the Dorper are less than that of the Merino ewe, but their fecundity and adaptions to a lower quality diet may increase the efficiency with which they can convert energy intake to weaned weight of lambs.

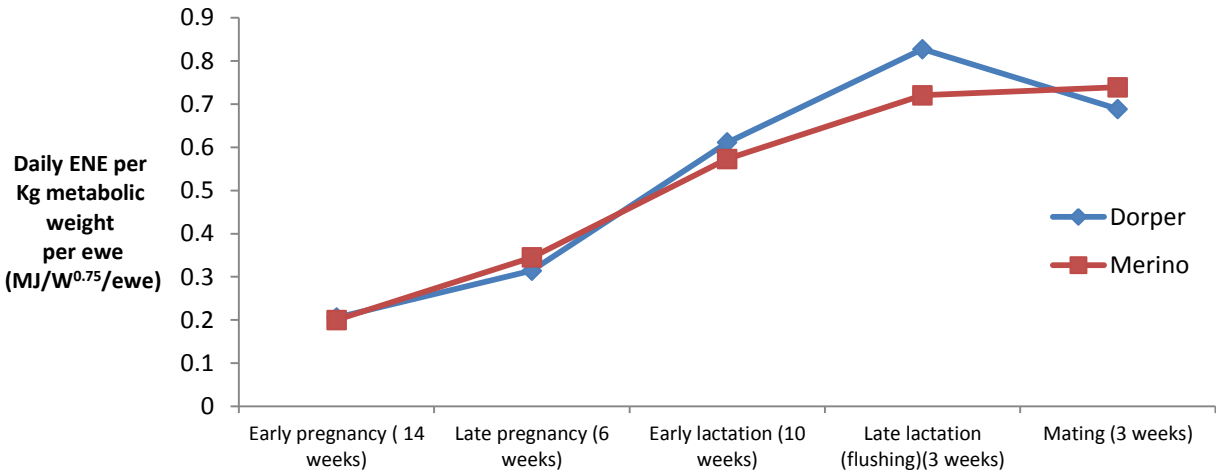

Figure 4: Daily estimated net energy intake (MJ) of Dorper and Merino ewes per kg metabolic weight per kg weight of weaned lamb produced (MJ/$W^{0.075}$/kg lamb weaned).

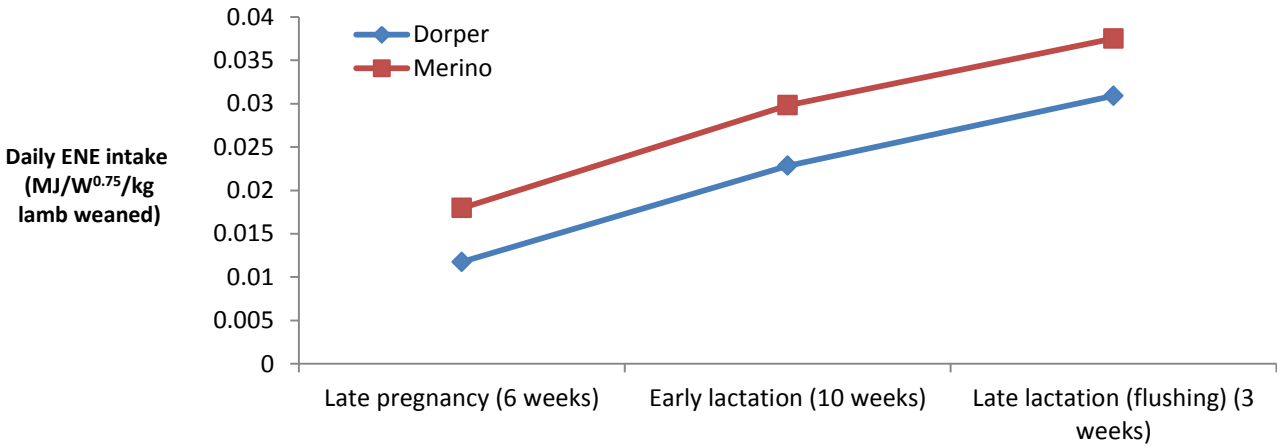

Figure 5: Daily estimated net energy intake per kg metabolic weight per kg of lamb weaned per ewe (MJ/$W^{0.75}$/kg lamb weaned). Data adapted from Basson et al. (1969). No data on variation was given.

In summary, breed differences in nutrient partitioning and the utilisation of body reserves mean that feeding Dorper ewes their nutritional requirements during late pregnancy and lactation, which is recommended for Merino ewes, may not be the most efficient use of feed resources. In fact, it may be detrimental and result in reproductive wastage if Dorpers are fed the same as Merinos, as shown the Australian study by Kilminster and Greeff (2011). Because of her increased body reserves, the Dorper ewe seems to have a much greater capacity to buffer her lamb against inadequacies in her energy intake. Although no research has been done on what the optimal condition score and pattern of live weight change is for the Dorper ewe during reproduction, it will undoubtedly involve a greater fluctuation in ewe live weight than what is recommended for the Merino. More research is needed into the optimal and most cost-effective nutrition of the Dorper ewe during pregnancy and lactation for the maximum reproductive efficiency of Dorpers to be achieved.

3.5 Reproductive efficiency of Dorpers

A high reproductive efficiency allows a higher total weight of lambs to be produced from less energy intake which has a large impact on profitability for the farmer. The efficiency of reproduction can depend on reproductive traits (fertility, fecundity, lamb survival, lamb growth) and number of lambings per ewe lifetime (annual verse accelerated mating) (Fogarty, 1984). Schoeman et al. (1995) found that composite breeds developed from Finnish landrace sheep were 84% more efficient than Dorpers in carcass weight of lambs produced per 100kg digestible dry matter intake per ewe. This was a result of the much higher reproductive rate and smaller size of the composite breeds resulting in lower energy requirements. However, in this study, reproductive rates of the Dorper were quite low compared to other studies at 83% of lambs born per ewe mated, and the breed does have the potential to reach the reproductive rates of the composite breeds in this study which were 120-134% lambing. However, Schoeman (1990) found that the reproductive efficiency of Dorpers was higher than Dohne Merino and SAMM ewes per metabolic weight. This agrees with other studies that have found Dorpers to be more efficient than Merinos as they produce heaver total lamb weights per energy intake per metabolic weight (Basson et al., 1969; De Waal and Biel, 1989a). Dorpers may also be more efficient than Merino type breeds as they can be mated every 8 months and have the capacity to produce double the number of lambs per ewe lifetime than the Merino (see Table 5). Dorpers may be less efficient than highly fecund breeds such as the Finn but more efficient than less fecund breeds such as the Merino.

In summary of this section on nutrition during reproduction, it is clear that more information is needed to formulate an optimal management system for Dorper ewes in Australia. To what degree the current system for Merinos can be applied is unknown, but differences between breeds are apparent which signifies a need for further investigation into how the Merino management system could be altered to accommodate the needs of the Dorper ewe. This needs to be done in order to

maximise reproductive rates of this meat breed if it is to compete with the extra income the Merino generates from wool production.

4. Finishing Dorper lambs

In commercial flock situations, the majority of the Dorper producer's income would be derived from selling lamb as sheep meat. Therefore, it is imperative that the best and most efficient feeding strategies are employed for rapid weight gain of lambs from weaning until slaughter. Lambs are often fed "finishing diets" which are high in protein and energy and allow the lamb to grow to its full potential. In this section, the research conducted on the growth rates of Dorper lambs from post-weaning until slaughter will first be discussed. Then, the feed efficiency of Dorper lambs when given finishing diets will be evaluated. Data from Dorper lambs will also be compared to other breeds.

4.1 Growth rates of Dorper lambs from post-weaning until slaughter

Published values for post weaning growth rates of Dorper lambs ranges and, not surprisingly, this depends largely on the diet they were fed. Average daily gains 260 g/h/day have been recorded on finisher pellets compared to 65 g/h/d when grazing pasture (Bunch et al., 2004; Kariuki et al., 2010; Salinas-Chavira et al., 2010). Table 7 shows the results of available studies that have measured growth rates in Dorper lambs from weaning until slaughter. As Dorper rams are often used as a terminal sire, some of the lambs are cross-breds as indicated. In breed comparison studies, growth rates of Dorper lambs tended to be higher than other hair breeds such as the Katahdin, St Criox, Pelibuey and Blackbelly (Burke and Apple, 2007; Burke et al., 2003; Lopez-Carlos et al., 2010). Compared to wool breeds, growth rates of Dorper lambs also tended to be higher (Bunch et al., 2004). Growth rates of cross-bred Dorper lambs were similar to cross-bred lambs sired by British breeds such as the Dorsett and Suffolk (Notter, 2004; Snowder and Duckett, 2003). However, there have been no studies with pure-bred Dorpers comparing them to pure-bred British breeds. The available data shows that the Dorper has the capacity for high growth rates, similar to or better than other breeds when fed a range of diets from weaning until slaughter.

Age at which a lamb reaches slaughter weight is very important in sheep meat production as generally, the longer the lamb stays on the property, the higher the feeding cost. In some production systems, lambs are sold to slaughter strait off their mothers, and are known as "suckers". This practice is used on many breeds with high growth potential such as Dorsets, Texels or Suffolks and can also be used with Dorpers. Getting the maximum number of sheep reaching slaughter weights early can have a large impact on profitability. When Dorper ewes are managed under grazing conditions in South Africa, Dorper lambs reach slaughter weight (40 kg) sooner than Merino or Afrino lambs and a higher percentage of the lamb flock

reaches this target weight in the first draft of lambs. These results have also been shown in Australia where, because of higher growth rates, younger age at slaughter and higher percentage of lambs reaching slaughter weights in the first draft, the meat production of Dorper lambs was much more economical than Merino lambs (Kilminster, 2010). Because of their high growth potential, Dorper lambs are able to reach slaughter weights sooner than wool-type breeds.

Table 7: List of references investigating average daily gain (g/day) of Dorper lambs from weaning until slaughter. Diet, breeding and the results of the breed comparison studies in terms of lamb growth rates are also included.

Average Daily Gain (g/day)	Diet	Pure or cross bred	Breed comparisons of lamb growth rate	References
187	Summer grazing	Dorper sired Dorset cross-bred ewe	Dorset = Dorper sired lambs	(Notter, 2004)
142	Dry lot (14% CP, 72% TDN)			
239	Feedlot pellets (18% CP, 71% TDN)	Dorper sire x Columbia ewe	Dorper = Suffolk = Columbia sires	(Snowder and Duckett, 2003)
105 (3-9 months of age)	Extensive, low quality pasture	Pure hair Dorpers	Hair Dorpers = Wool Dorpers	(Snyman and Olivier, 2002)
238	Housed (14.5% CP, 72% TND, 2.8 Mcal/kg DE)	Pure	Dorper>Katahdin and Pelibuey > Blackbelly	(Lopez-Carlos et al., 2010)
65	Natural pasture in semi-arid Kenya	Pure		(Kariuki et al., 2010)
261	Feedlot (14% CP, 2.6 Mcal/kg ME)	Pelibuey x Dorper	Dorper > Damara cross and Pelibuey	(Salinas-Chavira et al., 2010)
246	Feedlot (16.9% CP) formuled for moderate growth	Dorper x St Croix	Dorper X St Coix > Katahdin and St Croix	(Burke et al., 2003)
260	Finishing pellet (16% CP, 20% Fibre, 2% fat)	Dorper X St Croix	Dorper x St Criox > St Croix and wool types	(Bunch et al., 2004)
147	Grazing + 680g/h/d corn/soybean meal	¾ and 7/8 Dorper	Dorper > Katahdin> St Croix	(Burke and Apple, 2007)

4.2 Feed efficiency

Values for feed efficiency of Dorper lambs in the post-weaning period largely depend on the diet and there seems to be little differences between Dorpers and other meat and hair breeds (Table 8). Feed efficiency can be optimised by feeding the correct ratio of protein to energy, so comparing different studies which fed different diets is difficult. Table 7 shows values for feed efficiency of Dorpers that have been published. The least efficient values for the Dorper were recorded by Schoeman et al. (1993b) who fed a lower protein diet (10% CP) than the other studies and found Dorpers consumed 10.7 kg of feed intake per kg of weight gain. However, Salinas-Chavira et al. (2010) fed ration higher in protein (14%) and found feed efficiency of Dorper x Pelibuey lambs at 4.6. The only breed differences that were found in these studies was that Lopez-Carlos et al. (2010) found that Katahdin lambs were more efficient than Dorpers, Blackbelly lambs were similar to Dorpers and Pelibuey lambs were less efficient than the other three breeds. However, other studies used similar breeds and found no differences (Canton et al., 2009; Salinas-Chavira et al., 2010). Overall, feed efficiency of Dorper lambs between post-weaning and slaughter seems to be similar to other meat and hair breeds.

Gender differences may exist in Dorpers on the influence that diet and previous nutrition have on feed efficiency. Energy conversion in Dorper ram lambs has been shown to be higher after a period of feed restrictions of up to 50% for 9 weeks, compared to ad libitum feeding for the whole growth period (Marais et al., 1991a). However, this effect was not seen in Dorper ewes. Also, altering the concentrate to roughage ratio in the diet does not affect the efficiency of protein and fat disposition in Dorper sheep, but gender differences are also apparent in the sheep response to the diet (Marais et al., 1991b). The energy cost of synthesizing fat is higher than that of protein in both sexes and an increase in body mass decreases the efficiency of protein deposition. When the sexes were compared, it took ram lambs more energy to synthesise protein and less energy to synthesize fat compared to ewe lambs (Marais et al., 1991b). Values for Dorpers appeared to be similar to those found in Karakul and Mutton Merino sheep, but breed differences have been found in other studies ((Marais et al., 1991b) reference Meissner 1977 could not be found). Previous under-nutrition can increase the feed efficiency of Dorper ram lambs, but the ratio of concentrate to roughage in the diet doesn't appear influence the efficiency of protein and fat deposition in Dorpers (Marais et al., 1991a, b).

In conclusion, Dorper lambs have growth rates comparable to other meat breeds and higher than wooled breeds. Lambs have the ability to reach slaughter weights rapidly and a high percentage of lambs from the flock can be included in the first "draft" of lambs to market. Feed efficiency of Dorpers when fed finishing diets appears to be similar to other breeds. Overall, Dorper lambs have the potential to gain weight and utilise high quality finishing diets as well, if not better, than other breeds. Although breed differences may not be apparent when fed high quality

diets, the Dorper lambs may possess adaptions which allow them to survive in harsh environments that may alter their utilisation of low quality diets. These possible adaptions will now be discussed.

Table 8: Data on feed efficiency of Dorper and Dorper cross lambs post-weaning and possible breed differences.

Feed Efficiency (%)*	Diet	Pure or cross	Breed differences	Reference
7.1	Housed (14.5% CP, 10.9 MJ/kg ME)	Pure	Katahdin most efficient feed utilisation	(Lopez-Carlos et al., 2010)
4.6	Feedlot (14% CP, 10.9 MJ/kg ME)	Pelibuey x Dorper	No difference in feed efficiency between Dorper and Damara cross.	(Salinas-Chavira et al., 2010)
6.85	Finishing pellet (16% CP, 20% Fibre, 2% fat)	Dorper X St Croix	No breed differences	(Bunch et al., 2004)
8.3**	Feedlot pellets (18% CP, 10.7 MJ/kg ME)	Dorper sire x Columbia ewe	No differences between Dorper, Suffolk and Columbia sired lambs	(Snowder and Duckett, 2003)
5.0	15-19% CP, 2.2 Mcal/kg DM (9.2 ME)	Dorper X Pelibuey	No breed differences between Dorpers, White Dorper, Katahdin/Pelibuey cross Pelibuey lambs	(Canton et al., 2009)
5.4		White Dorper X Pelibuey		
10.7	Pellets, 10% CP, 10.5 MJ ME/kg DM	Pure	No differences between Dorper and Finn composite lambs	(Schoeman et al., 1993b)

*Feed efficiency (%)= kg feed/kg weight gain

** Converted from 0.12 feed efficiency ratio

5. Adaptations of Dorpers

In our increasingly variable climate, it is becoming more important to produce resilient sheep that are readily adaptable to changes in the quality and quantity of feed resources. In the often harsh Australian environment, sheep that can cope with periods of low food availability are valuable assets. Sheep can be adapted to feed scarcity in one or more of the following ways:

- developing a low metabolic requirement and an ability to reduce metabolism
- increasing digestive efficiency and ability to utilize high fibre feed
- greater deposition of nutrients in the form of fat as a feed reserve (Mirkena et al., 2010)

As well as adaptions to feed scarcity, other adaptations such as resistance to worms and grazing behaviour can also have economic impact to farmers. The extent to which Dorpers possess all these adaptions will now be discussed and compared to other breeds, particularly the Merino. The possible production benefits to these adaptions will also be evaluated.

5.1 Metabolic requirements and the ability to reduce metabolism

Having a low metabolic requirement and an ability to reduce metabolism is an advantage when feed is scarce. The energy requirements of desert adapted goat breeds are lower than that predicted by their body mass and they have been found to have 36% lower metabolic requirements per metabolic body weight than non-desert goats (Silanikove, 2000). They also have the ability to reduce their metabolism and have 53% lower fasting heat production under feed restriction than non-desert goats (Silanikove, 2000). Like these desert adapted goats, Dorpers are also able to survive in some of the harshest deserts in the world, therefore, they must possess some adaptions compared to temperate breeds that allow them to survive in these challenging environments.

The question most relevant to this review is whether Dorpers possess lower energy and protein requirements than other breeds of sheep which would be very beneficial when grazing under the harsh conditions found in many parts of Australia. It seems the only study to investigate this is one by Degen and Kam (1991) which sought to determine if Dorpers possessed similar physiological adaptions to desert environments as other species that inhabit the Negev desert such as Bedouin goats, camels and donkeys. Since these animals survive by having lower energy and nitrogen requirements than other non-desert breeds, it was hypothesised that this is also the case for Dorpers, otherwise they could not survive under such extreme conditions. However, the authors were perplexed to find that this was not the case for Dorpers. They found that Dorpers had similar energy and nitrogen requirements to other sheep breeds and their requirements appeared to be greater than some

other desert herbivores. The authors suggested that the key to the Dorper's survival in the desert could be that, as well as food shortages, Dorpers often have limited access to water. Nitrogen and energy requirements of desert sheep and goats are lower when drinking water is reduced. Therefore, Dorpers may have lower energy requirements when food as well as water is restricted, as often occur in the desert. Also, Dorpers could take a similar strategy to ibexes and deposit body reserves rapidly when food is available and utilize these reserves when food is limiting. It appears that the most crucial physiological adaption that Dorpers possess for survival in harsh environments is not a lowering of requirements, but rather having a greater ability to change their requirements based on the food and water resources available.

The adaptions that Dorpers possess to harsh environments may mean that their feed requirements are slightly different from those predicted by their body weight using the current feeding standards for livestock. In a West Australian study, a pelleted diet (9.3 MJ ME/kg and 11.5%CP on DM basis) was fed to Dorper lambs so they either gained 100g/h/d or lost 100g/h/d according to their individual requirements (SCARM, 1990). Dorper lambs gained 88% more weight and lost 81% less weight than predicted from their body mass. This discrepancy from the predicted weight gain and loss was also seen in the Merinos and Damaras included in the study but it tended to be more pronounced in the Dorper. Another West Australian study fed Dorper ewes their maintenance requirements during pregnancy and lactation, based on what is recommended for Merino ewes, and found that in Dorper ewes instead of maintaining condition as was predicted by the diet available, ewes gained condition (Kilminster, 2010; Kilminster and Greeff, 2011). These studies suggest that feed requirements for growth, maintenance and weight loss of Dorper sheep may be slightly different than those predicted by their metabolic weight.

There is evidence of a lower feed intake per metabolic size in Dorpers compared to Merinos when grazing low quality pasture, but the effect may be less pronounced when fed higher quality diets. When feed intake was measured in lactating Merino and Dorper ewes that were grazing low quality pasture in South Africa, both breeds consumed the same amount of herbage despite Dorper ewes being around 25% heavier than Merino ewes (De Waal and Biel, 1989a). Therefore, Merino ewes had a higher herbage intake per metabolic size than Dorper ewes (DOMI/Wkg $^{0.75}$ /day). This could be because, as often occurs during lactation when grazing a low quality diet, the maximum gut-fill was reached so although Dorpers required more to meet their higher demands, they physically could not consume any more forage. However, this effect has also been shown when comparing Dorper and Merino wethers when grazing forages which suggests that this also occurs in other classes of livestock when feed requirements are lower than during lactation (refer to (De Waal, 1995; Engels et al., 1974). So rather than simply being at maximum gut fill, this could mean that either Dorpers have lower metabolic requirements than Merinos or, Dorpers are able to utilise the low quality component of their diet more efficiently,

thus gaining more energy from the feed they consumed. Results from other studies suggest the latter is more likely. When a high quality diet (lucerne hay and maize) was fed to lactating Dorper and Merino ewes, their feed intake per metabolic size was similar (Basson et al., 1969). If feed intake per metabolic size is less for the Dorper when fed a low quality diet, but similar when fed a high quality diet, then rather than having lower metabolic requirements, Dorpers may be able to utilise low quality diets more efficiency than Merinos.

In summary, it appears that Dorpers do not possess the same extreme metabolic adaptations to desert environments that desert goats do, but this may be seen when water is restricted as well as food. There is evidence that the nutrient requirements of Dorpers for growth and reproduction may be less than that predicted from their body mass and less than the Merino ewe. However, it is unclear whether these differences are a result of different metabolic requirements or, as is more likely the case, due to other adaptions such as their digestive efficiency, particularly on low quality diets.

5.2 Digestive efficiency and ability to utilise low quality foods

Rather than having lower metabolic requirements, the adaptations that Dorpers possess to help them survive in harsh environments could be associated with an increased digestive efficiency. This would allow them to obtain more protein and energy from the same amount of food. This section will investigate firstly whether there are differences between sheep breeds in digestive efficiency, secondly, the possible physiological adaptations of the rumen that could be behind these differences and thirdly, if these adaptations occur in Dorpers and what could be the benefits to production parameters.

Breed differences

There does seem to be differences between sheep breeds in their digestive efficiency. Table 9 lists the studies that have investigated digestive efficiencies of different breeds and summarises the differences found. Damara sheep use different methods to obtain more energy from both low quality and high quality food than Merinos in a study done in Australia (Wilkes et al., 2012). When fed a low quality diet, Damaras had a higher apparent energy digestibility and dry matter digestibility than Merinos while having similar feed intake. When fed a higher quality diet, Damara sheep digested the diet similarly to Merinos, but they increased their feed intake of the diet to 14% more than Merinos which allowed them to gain more weight. Therefore, Damara sheep could utilise a low quality diet more efficiently than Merinos and also capitalise on a higher quality diet by consuming more and gaining more weight. Similarly, Silva et al. (2004) found that intake of dry matter was higher in hair lambs (Santa Ines) when consuming both low quality and high quality diets than in temperate wool lambs (Ideal x Ile de France). Hair lambs also had a higher digestibility of the diets, in particular the neutral detergent fibre of the diets which was

44% more digestible in hair lambs. Hair lambs also retained more nitrogen, particularly when fed higher quality diets and were more responsive to changes in nitrogen ingestion by changing their nitrogen retention. The authors concluded that hair lambs showed a higher nutrient consumption and utilisation efficiency than wool lambs and were more responsive to low quality diets. A later study by Silva et al. (2007) found that Santa Ines hair lambs were also more efficient at using protein for body weight gain than Ideal x Ile de France wool lambs. These studies show that there are differences between hair and wool lambs in the digestibility and utilisation of diets which could allow hair lambs to have an advantage when consuming low quality diets. Although the Dorper was not specifically used in these studies, extrapolating the data suggests that since they are also an arid hair breed, they may also utilise low quality diets more efficiently than wool breeds such as the Merino.

In, studies where cross-breds were used, results were not as clear cut as the pure-bred studies mentioned above. In a study by Lunsford et al. (2006), White Dorper x Polypay and ¾ white Dorper ¼ Polypay lambs were compared to pure Polypay lambs. Digestibility of the diet were not different between breeds when fed a 60% hay and 40% concentrate ration, but when the concentrate level went up to 90%, Dorper cross lambs tended to have a higher digestibility of dry matter ($P<0.1$), but digestibility of nitrogen, NDF and ADF was not different between breeds. Nitrogen retention values tended to be higher in ½-bred Dorper lambs but the difference was not significant. Only six sheep per breed were used in this experiment and the "high roughage" diet was still 40% concentrate. In addition, both breeds originate from Dorsets thus, it is not surprising that differences were minor in this study. When comparing Barbados Blackbelly, Dorset and Blackbelly x Dorset breeds, the cross bred sheep had a lower total mean retention time of digesta in the rumen than the purebreds and a higher digestibility of crude protein. However, in other digestive parameters, the Blackbelly had a larger gut fill and longer rumen retention time than the other breeds and slower rate of passage than the Blackbelly X Dorset sheep. Not surprisingly, breed differences between hair and wool type sheep are complicated by crossing breeds and in cases where the breeds are from similar lineage, such as the Dorper and Polypay, breed differences may be less apparent.

Table 9: Summary of papers investigating feed utilisation in different sheep breeds.

Breeds	Differences found	Reference
Hair (Santa Ines) vs wool (Ideal x Ile de France)	Protein requirements for body weight gain higher in hair lambs. Hair lambs had more efficient protein utilisation.	(Silva et al., 2007)
Damara vs Merino	Higher digestible energy intake in Damaras through higher dry matter digestibility on low quality feed and higher feed intake on high quality food.	(Wilkes et al., 2012)
Merino vs Churra	Degradation rates in rumen higher in Churra sheep when fed fibrous diets but no breed differences when given high quality forage.	(Giraldez et al., 1994; Ranilla et al., 1998)
Cheviot vs Suffolk	Cheviot had greater digestive efficiency through greater digestibility of dry matter, particularly on low quality diet.	(Givens and Moss, 1994)
Hair (Santa Ines) vs wool (Ideal x Ile de France)	Hair lambs had more efficient digestibility of dry matter and utilised low quality diets better than wool lambs.	(Silva et al., 2004)
Dorper x Polypay vs Polypay	Digestibility of high concentrate diet higher in Dorper crosses, no difference in high roughage diet.	(Lunsford et al., 2006)
Hair sheep, Blackbelly, Katahdin, St Criox	Differences in nitrogen digestibility and absorption. Differences in dry matter digestibility.	(Wildeus et al., 2007)
Blackbelly, Dorset, Blackbelly x Dorset	No differences in digestibility of DM or NDF. Differences in ruminal retention time, rate of passage and gut fill.	(Mann et al., 1987)

Breed differences in the utilisation of diets have also been noted within breed types. Giraldez et al. (1994) found differences in degradation rates in the rumen of Churra and Merino sheep that may suggest differences in their ability to digest fibrous diets. However, when fed good quality forage hay, there were little differences between breeds in digestibility of the diet or digesta flow from the rumen (Ranilla et al., 1998). Even within British breeds of sheep there seem to be differences in digestive efficiency. The Cheviot has been found to have a greater digestive efficiency than Suffolk cross animals due to a higher digestibility of DM, OM, and DOM content of DM. Again, this difference tended to be greatest when fed low quality diets. The authors suggest that Cheviot sheep have been selected for grazing poor quality pastures in highland areas and in response, have a greater digestive ability. Similarly, there are also differences in digestive capacity and utilisation within hair breeds. The Katahdin hair breed has been shown to have a higher apparent digestibility of most feed fractions compared to the Barbardos Blackbelly and have a higher nitrogen utilisation and efficiency compared the St Criox and Blackbelly (Wildeus et al., 2007). It has also been shown that breed could be more important than age and body weight when evaluating different types of feed (Givens and Moss, 1994). Overall, it is clear that there are differences between breeds in digestive efficiencies.

One common theme in these studies tends to be that breed differences are more pronounced when fed a low quality diet. This has been shown to be the case when comparing hair and wool breeds (Silva et al., 2004; Wilkes et al., 2012) and within wool breeds (Givens and Moss, 1994). Breeds originating from areas where they must survive on low quality pasture, such as arid breed like the Damara and highland breeds like the Cheviot, seem to have developed the ability to utilise low quality forages more efficiently. The reason they are able to utilise low quality diets better could be associated with adaptations in their rumen function.

Possible adaptions in rumen physiology

Differences in utilisation of low quality food could stem from differences in conditions in the rumen. De Waal (1995) studied rumen fermentation in lactating Dorper and Merino ewes over 3 years when grazing natural pasture and supplemented with protein and energy at different levels. They found no differences between breeds in the effects of the supplementation. However, they found that *in sacco* DM disappearance of winter pasture was 22% higher in Merino ewes than Dorpers. The authors attributed this to differences between breeds in the pH of the rumen. The ruminal pH of the lactating Dorper ewes was consistently lower than that of the Merino ewes (average 6.7 for Merinos and 6.6 for Dorpers) (De Waal and Biel, 1989c). The authors offer little justification for these differences but suggest that lower pH in the rumen could be linked to a higher ruminal activity and that differences in rumen pH have been found between other breeds (Hampshire, Romney, Rambouillet and Merino in a study by Olson et al. (1968). The complexity of interactions in the rumen makes it difficult to predict the effects of the slightly lower

pH of the Dorper ewes in this experiment. It is interesting however, that although Dorpers retained more of the fibrous component of their diet in the rumen for longer, the *in sacco* disappearance of maize meal, the concentrate component of the diet, was similar between breeds (De Waal, 1995). This indicates that Dorpers are able to retain lower quality roughages for longer in the rumen than Merinos, but not higher quality, more digestible foods.

If roughage is retained for longer in the rumen of Dorpers, they need to compensate for this by either lowering their food intake, or by having a larger gut fill than Merinos. In the experiment by De Waal and Biel (1989b), even though Dorpers retained forage in their rumen for longer than Merinos, food intake between breeds was similar. Therefore, it seems the gut fill of the Dorper may be larger than the Merino. Although this has not been tested, the hair breed Barbardos Blackbelly, which is adapted to low quality pasture, has a 32% larger gut fill than the Dorset (Mann et al., 1987). Since the abdominal girth of the Dorper lamb is larger than that of the Blackbelly (Lopez-Carlos et al., 2010), and they are both hair breeds adapted to low quality foods, it is possible that the Dorper could have a larger gut fill than the Merino. When Damaras were found to have a greater digestibility of dry matter of low quality forages than the Merino, the authors suggested it could be attributed to a slower rate of passage and larger rumen volume (Wilkes et al., 2012), which agrees with this theory. It is possible that Dorpers have a greater capacity to increase their rumen volume allowing low quality roughages to be retained longer in the rumen, thus increasing utilisation, while maintaining a similar food intake than Merinos. This increased utilisation of low quality diets should theoretically lead to production benefits.

Production benefits

There is extremely limited information on whether the possible increased utilisation of low quality feed of Dorpers translates to production benefits such as increased weight gain. The only study available is a small experiment in Australia that attempted to test whether Dorper lambs had a productive advantage over Merino lambs or Dorper cross Merino lambs when grazing cereal stubbles over summer in Western Australia for 6 weeks (Hilliam et al., 2012). The grazing value of the stubbles was less than the lamb's maintenance requirements. Merinos were lighter, leaner and had a lower condition score compared to Dorpers at the start and end of the experiment. Cross-bred lambs lost more weight the purebred Dorper lambs but there was no difference between Merinos and Dorpers. There were no differences between breeds in the change of body composition (% fat, lean and bone mineral content) from the start until the end of the experiment or in blood metabolites glycerol, non-estified fatty acids or urea. Although not mentioned by the authors, Dorpers were 7 kg heavier than the Merinos which mean they would have had higher metabolic weight and higher energy requirements than Merinos, yet they maintained weight as well as the Merinos when grazing the same diet. It is interesting that factors other than starting live weight accounted for 87% of the variation in weight

change seen in these lambs. Further investigation into the major contributing factors of this variation such as intake, digestibility and efficiency, could yield valuable information on how farmers can optimise sheep production from stubbles. As the authors state, there are many limitations to this study such as small sample size and it cannot be considered a "breed comparison" study. The limited time frame is also a factor since sheep in cereal zone of Western Australia often graze on stubbles for six months rather than six weeks. Further investigation is required to determine if breed differences exist above the large within breed differences. However, this does suggest that Dorper lambs can maintain their body weight as well as Merinos when grazing low quality cereal stubble in Australia.

In summary, breeds originating under harsh grazing conditions, such as arid breeds like the Dorper, tend to have a higher digestibility and utilisation of low quality forages. Dorpers may have an advantage over Merinos when fed a low quality diet as they may have a better capacity to utilise low quality roughage by a slower rate of passage through the rumen and possibly an increased gut fill. However, in the very limited work that has been done on Dorpers in Australia, a small study suggests there are little production benefits of Dorpers of Merinos when lambs graze stubbles over a short period of time. However, Dorpers may possess other adaptions such as the deposition of body reserves which may have production benefits.

5.3 Deposition of body reserves

In many natural ecosystems, as well as farms, there is a "boom" and "bust" time where conditions are good for a short period when food is plentiful such as during spring, and then a time when there is little food available such as the summer and Autumn food "gap". This variation in food availability is linked to climate variability, the effects of which may be more pronounced in the future. The ability of an animal to capitalise on the good times by gaining weight rapidly and then utilise these body reserves when nutrition is limited, could be a major advantage especially during reproduction. This section will firstly look at the limited work that has been done on how Dorper lambs handle nutritional stress and then how deposition of body reserves may be important during reproduction.

There is evidence of the Dorper's capacity for rapid weight gain when feed is available and slow weight loss when feed is limited. A study was conducted in Western Australia to determine the response of Merinos, Dorpers and Damaras to nutritional stress (Scanlon et al., 2008). These breeds were fed to either gain or lose 100g/head/day of weight by feeding different quantities of a pelleted diet while run in a bare paddock but fed individually (9.3 MJ ME/kg and 11.5%CP on DM basis). Dorpers gained weight more rapidly than the Merinos or Damaras (188 g/h/d Dorper, 148 for Damara and 139 for Merino ($P<0.05$)). When fed to loose 100g/h/d, Dorpers tended to lose weight more slowly and only lost -19g/head compared to Merinos that lost -28g/h/d and Damaras who lost -48 g/h/d but there was no significant difference

between breeds in the weight loss group (P>0.05) (Scanlon et al., 2008). After the first 20 days of the restricted feeding, there was little further weight loss in the restricted feeding groups suggesting they had adapted to a lower energy intake. This was only a small study with only 12 ram lambs (4-6 months of age) of each breed tested so results should be taken lightly. However, it does indicate the Dorpers ability to gain weight rapidly when nutritional conditions are good and lose weight slowly when nutrients are limited.

This tactic could be most beneficial during the reproductive phase. As previously discussed in the reproduction section, Dorper ewes tend to utilise their body reserves more during peak lactation than Merino ewes (Basson et al., 1969; De Waal and Biel, 1989a) and Dorper ewes are heavier than Merino ewes suggesting that they have more body reserves to utilise (Basson et al., 1969; De Waal and Biel, 1989a; Kilminster and Greeff, 2011; Snyman and Herselman, 2005). Dorper ewes create more body reserves during the less-nutritionally demanding times of the reproductive phase such as mating and early pregnancy, so that they can draw on those reserves during the time of peak nutritional demand during lactation. These body reserves are particularly important when grazing low quality forages because ewes cannot physically consume enough of the forage to meet their nutritional demands during lactation. As previously discussed, utilising their body reserves allows Dorper ewes to maintain high milk production even when only consuming around 40% of their feed requirements (Joubert, 1972). Whereas in leaner breeds, such as the Merino, milk production is much more sensitive to changes in food availability (Thompson et al., 2011). This has major implications for production systems as farmers may be able to feed less to Dorper ewes during late pregnancy and lactation compared to Merinos, without having a negative effect on lamb production then allow ewes to re-gain body condition in less nutrient demanding times such as mating.

The reproductive benefits of storing more body reserves are evident in the higher production rates of the Dorper compared to leaner breeds. Dorpers can wean more lambs than the Merino, Dohne Merino and SAMM under conditions of good nutrition (Basson et al., 1969; Schoeman, 1990). However, this adaption of high body reserves would be even more advantageous under extensive conditions on a lower quality diet. Manyunchi et al. (1991) has shown that when grazing better quality pasture in South Africa Dorper ewes had a similar number of lambs weaned as Merinos, but Dorper lambs grew 45 % faster than Merinos. When grazing poorer pastures, Dorpers weaned 18% more lambs than Merinos and their lambs grew 55% faster than Merinos (Snyman and Herselman, 2005). Dorper ewes also weaned 12% more lambs than SAMMs under extensive conditions (Manyunchi et al., 1991). It is unknown whether production benefits of Dorpers over Merinos exist when grazing extensively in Australia as, in the only study to investigate reproduction in Dorpers, ewes were fed to optimal management for the Merino which incurred production losses in Dorper ewes through over-feeding (Kilminster and Greeff,

2011). The strategy of the Dorper ewe to deposit and then utilise body reserves for use when nutrients become limiting would buffer her lamb against nutrient restrictions which would be most evident when grazing low quality pastures.

5.4 Resistance to parasites

There has been a body of work done in Africa on resistance of different sheep breeds to worms. With drenching of sheep for worms uncommon in many extensive production systems in Africa, coupled with high worm burdens particularly in the sub-tropical areas, the survival of the sheep depends on its resistance and resilience to worms. Red Maasai sheep are much more resilient and resistant to worms than Dorpers in experiments in the sub-humid environment of the Kenyan coast, (Baker et al., 2004; Baker et al., 2003; Nguti et al., 2003) and other areas (Mugambi et al., 1997; Wanyangu et al., 1997). Sabi sheep are also more resistant to worms than the Dorper in a semi-arid environment (Matika et al., 2003). The Dorper's resistance and resilience to worms is similar to the Blackhead Somali and higher than the Romney Marsh (Mugambi et al., 1997). With a low to moderate worm burden, the three hair breeds of Dorper, Katahdin and St Criox had a similar resistance to infection. However, under a high level of infection, Dorper lambs were less resistant to worms than the other hair breeds. Under low to moderate worm infections, all hair breeds had a greater worm resistance than Suffolk lambs (Burke and Miller, 2004). When faecal egg count was similar between Dorper and Suffolk lambs, packed cell volume (a measure of anaemia) was greater for Dorper lambs suggesting a greater tolerance or resilience to worms (haemonchosis) (Burke and Miller, 2004). Under a low worm burden in Western Australia there was no difference in worm egg count between Dorpers, Merinos and Damaras (Kilminster, 2010). Dorpers do not possess the extreme resistance to worms that the Red Maasai does, but under the low to moderate worm burdens commonly found in Australia, its resistance is comparable to other hair breeds, the Merino and it may be more resilient than the Suffolk.

The only other study found that investigated the disease resistance of Dorpers was on footrot. Burke and Parker (2007) tested the response to exposure and response to treatment in Dorset, ½ Dorper. ¾ Dorper, Gulf coast Native, Katahdin and St Criox breeds. Under exposure to footrot, ½ Dorper sheep had a higher number of areas infected and ¾ Dorper sheep had a greater percentage of sheep with odour when infected than the other breeds. However, foot score was similar among breeds and all breeds had the same response to treatment. Dorper sheep may have a slight disadvantage when exposed to footrot, but respond to treatment as well as other breeds.

5.5 Response to heat stress and water intake

The hot and dry environment in many parts of Australia may favour breeds that can better cope with these conditions. Hair breeds are thought to be better adapted to

heat stress than wool breeds (Wildeus, 1997). For example, Blackbelly sheep are more heat tolerant than Dorset sheep as shown by a lower rectal temperature and respiration rate when heat stressed (Ross et al., 1985). A study in semi-arid Queensland measured the rectal temperature and respiration rates of the Merino, Damara, Dorper, Poll Dorset, Rambouillet and SAMM rams prior to mating. Since heat stress is implicated in low fertility in this region, it was hypothesised that arid breeds may be able to cope with heat stress better and have increased reproductive rates, but only three rams were used in this trial. The only breed differences that were found were that, unlike the other breeds, the rectal temperature of Damara rams did not increase with the rise in ambient temperature during the day and Damaras also had a lower respiration rate. There were no differences in the reproductive rate of the different ram breeds. This suggests that even though Dorpers are an arid breed, they may not have the same adaptions that the Damara and other hair breeds possess that allow them to cope better with heat stress.

This is also evident when compared to the Blackheaded Persian as the water intake of the Dorper seems to be less efficient than that of its parent breed. The Blackhead Persian was 53% more efficient at utilising water intake for weight gain (water intake/kg weight gain) than the Dorper and 77% more efficient than the SAMM (Schoeman and Visser, 1995b). The weekly water consumption of the Dorper and SAMM breeds increased twice as much per 1^{o} C increase in ambient temperature compared to the Blackheaded Persian (Schoeman and Visser, 1995a). It could be that the adaptations to heat stress that the Blackheaded possess may not have been fully passed on the Dorper because of the infusion of the Dorset, a temperate breed that would not possess these adaptions. This may explain why the Dorper may be less tolerant to heat stress than other arid hair breeds such as the Damara.

The Dorper does have the ability to rapidly consume water after being subjected to water restrictions. When water became available after being withheld for 4 days, Dorpers could immediately consume more than the amount of body mass that they had lost through dehydration (Degen and Kam, 1992). Few other animals can do this, even a camel can only consume 58% of their body mass loss immediately after dehydration (see Degen and Kam (1992)for review). This strategy of water intake has similarities to their strategy for coping with limited food availability by gaining weight rapidly when food becomes available to replenish body reserves. This “boom and bust” method for coping with fluctuations in food and water scarcity is likely to be the reason that Dorpers can cope well in harsh arid environments.

5.6 Diet selection and grazing behaviour

Differences have been found in the grazing behaviour and diet selection of Dorpers compared to Merinos. Brand (2000) reviewed data from many studies done in South Africa on the grazing behaviour of Dorpers, particularly, comparing them to Merinos. Unfortunately, much of the original data that Brand (2000) refers to for this review is

written is Afrikaans or is unable to be sourced in Australia therefore, where original references could not be found, Brand (2000) will be referenced along with the original author. In this review Brand (2000) made these conclusions about the grazing behaviour of Dorpers compared to Merino-type breeds:

- Dorpers are less selective grazers compared to Merino-type breeds
- Dorpers utilised more shrubs and bushes and less grass
- Dorpers utilised a larger number of different plant species
- Dorpers walked less to select food and grazing sites
- The relative trampling factor for Dorper sheep was less than that of Merinos.

Diet selection

Du Toit (1998) tested the diet selection of Merino and Dorper sheep on three different range types in South Africa and different seasons. The diets selected by Dorpers and Merinos were between 97-75 % similar showing that the differences in diet selection are relatively small in the scheme of their whole intake. However, in general, Dorpers chose to consume more shrubs, trees and woody plant components than Merinos whereas Merinos selected more grasses and annuals. This agrees with results from Roux (1992) (Brand, 2000) who showed that Dorpers selected more shrubs than Merinos (35.7% compared to 13.9%) while Merinos selected more grass compared to Dorpers (86.1% vs 63.7%) when grazing native vegetation in South Africa. These studies also showed the Dorpers utilised a greater spectrum of plant species than Merinos (Brand, 2000; Du Toit, 1998; Roux, 1992). In contrast, when grazing pasture with a higher grass content and fewer shrubs, the diets of Merinos and Dorpers appeared to be similar as measured through chemical composition and *in vivo* digestibility (Engels et al., 1974). In general, when both shrubs and grasses are equally available, Dorpers consume more shrubs while Merinos consume more grass. This data is most applicable to rangeland systems in Australia, but diet selection may also be different when grazing stubbles.

Dorper sheep may be more willing to select lower quality parts of wheat stubble. *Brand and Franck (1998)* (Brand, 2000) grazed Dorper and SAMM wethers on wheat stubble at either one or two ewe units per hectare for 5 months. They found no differences between breeds in diet selection on the low stocking rate, but on the high stocking rate, Dorpers selected diets with a lower CP and higher NDF than SAMMs. The authors suggest that under a high stocking density Dorpers are more willing to select a lower quality diet than SAMMs. As discussed previously, Dorpers do not appear to have a nutritional advantage over Merinos when grazing stubbles for a short time (6 weeks) in Australia (Hilliam et al., 2012). However, the results from Brand and Franck (1998) suggest breed differences could be more apparent under more trying conditions of higher stocking rate and longer grazing time on stubbles.

Grazing behaviour

Dorpers and Merinos seem to differ in their grazing habits. *Roux (1992)* (Brand, 2000) found that Merinos grazed particular areas intensively for longer periods of time whereas Dorpers did not concentrate their grazing as much. Merinos also walked longer distances to select food or areas to graze whereas Dorpers walked shorter distances to find their next grazing area. In contrast, early in the Dorper's development in 1948, it was found that the Black headed Persian x Dorset horn (parent breeds of the Dorper) walked more per day than Merinos (Brand, 2000; Louw et al., 1948). It was suggested that more extensive grazing habits was the reason for these breeds being harder to contain with fences, a behaviour often noted by many Dorper producers in Australia. Since the study by *Roux (1992)* (Brand, 2000) was the most comprehensive, it is likely that there are differences in grazing habits between Dorpers and Merinos.

Grazing habits of animals can have a big impact on the environment, particularly in rangelands. The "trampling factor" of sheep breeds and goats was calculated using elements like bodyweight, stride length and hoof-print area to measure the effect of trampling on the ground (Brand, 2000; Roux and Schlebusch, 1987). Dorpers had a lower "trampling factor" than Merinos and since Dorpers walked less distance per day than Merinos, their trampling was further reduced compared to Merinos (Brand, 2000; Roux and Schlebusch, 1987). Grazing habits over a long period of time also have major influence on the composition of species that exist, especially in rangelands. Barnard (1987) (Brand, 2000) compared the effect that different animal species had on the numbers of palatable plants, less palatable plants, grasses and total plants in the rangelands of South Africa. Dorpers were measured at 4.3 sheep units/ha for 13 years whereas the Merinos where grazed at 4.8 units/ha over a period of 7 years. Grazing Dorpers resulted in an increase in total plants by 7.8% and this consisted of a 5.1% increase is grass, 3.2% increase in palatable plants and a 6.5% increase in less palatable plants. In contrast, grazing Merinos resulted in a -3.4% decrease in total plants consisting of a -1.7% decrease in grass, -7.7% decrease in palatable plants and a 1.7% increase in less palatable plants (Barnard, 1987). This shows that small differences in grazing habits can have large impacts on the quality of grazing country over a long period of time.

Overall, the less selective grazing habit of Dorpers over Merinos can have many advantages. It allows Dorpers to utilise more sources of forage such as shrubs and trees and utilise a larger range of species. Being less selective also means they may have a lower environmental impact through less trampling and allowing palatable species to regenerate. However, on a cautionary note, the few studies that show this environmental impact have not been repeated and were not published in peer-reviewed journals. All of these studies were done in South Africa and it is unknown if similar advantages would occur in Australia. Being less selective grazers in a crop/livestock system in Australia may allow Dorpers to better utilise crop stubbles with a high stocking rate and utilise shrubs such as saltbush. This also

suggests that Dorpers may be better suited than Merinos to grazing rangelands in Australia, but these assumptions require further investigation.

6. Conclusions

The major conclusions of this literature review are as follows:

- Dorpers have a high reproductive potential per ewe lifetime due to a high percentage of lambs born per ewe mated, ability to mate every 8 months and early sexual maturity.
- Optimal nutrition for the Dorper ewe during reproduction is unknown but it is likely to involve more fluctuation in condition score than what is recommended for the Merino ewe due to the ability of the Dorper to utilise its more abundant body reserves.
- Dorpers are likely to possess adaptations that allow them to utilise low quality diets more efficiently and their grazing behaviour and diet selection can differ from Merinos.
- More research is needed on the nutrition of the Dorper during reproduction and whether adaptions to low quality diets translate to production benefits in Australian farming systems.

The high reproductive rates of the Dorper could greatly contribute to increasing sheep numbers in Australia and help fill the increasing demand for Australian sheep meat. Over a ewe lifetime, Dorper sheep have the potential to produce over double the number of lambs than Merino ewes. The good growth potential of these lambs could help fill export markets for sheep meat and the less-seasonal nature of Dorper lamb production could support a continuality of supply for domestic abattoirs. Dorper lamb production suits both intensive systems where 2.3 lambs per ewe per year can be achieved (Basson et al., 1969), and extensive systems where ewes can produce around 1.45 lambs per year under poor grazing conditions with no supplements (Cloete and De Villers, 1987; Snyman and Olivier, 2002). The early maturity of Dorper ewes means that young ewes can be incorporated into the breeding flock at around 8 months of age, provided they are above 40 kg, and Dorper ewes can remain productive for up to 7 years of age. Dorpers could greatly contribute to increasing Australian sheep numbers in both intensive and extensive production systems. However, it is imperative that we capture this reproductive potential by optimising the nutrition of the ewe.

Livestock production systems are most profitable when they achieve maximum production levels from minimal production costs. In Merinos it is most economical for farmers to feed the ewe to her maintenance requirements as production parameters in the Merino such as wool and milk production are sensitive to inadequacies in energy intake, particularly around lambing when feed requirements are highest. In the Dorper however, when energy intake becomes limiting, their more abundant

body reserves are readily utilised to compensate for this so that milk production can be maintained. Therefore, feeding the Dorper ewe to her energy requirements during late pregnancy and lactation would increase feed costs to the farmer but may not result in increased production levels. Therefore, rather than closely matching feed availability to feed requirements as recommended for Merinos, Dorper producers may be able to maintain a steady, but adequate, feed availability and allow the Dorper ewe to deposit body reserves during period of low demand such as mating, and then utilise these reserves during lactation. However, like what has been done for the Merino, it is essential to determine the productive consequences on the Dorper ewe and her lambs from changes in condition score during reproduction. This will allow economic analysis to ascertain the most profitable nutritional regime for Dorpers during reproduction under different farming systems in Australia.

Dorpers possess adaptations that make them a robust sheep breed which is able to cope well with variations in food availability and quality. In the face of increasing climate variability it is essential to have sheep which can both capitalise on good seasonal conditions but still perform under challenging ones. The ability of the Dorper to deposit and then utilise its body reserves when needed and utilise low quality foods make it a very resilient sheep breed. Having these adaptations may not only increase production rates from fewer inputs, but also improve survival and welfare of animals when faced with the harsh conditions often experienced in droughts in Australia. The less seasonal mating of Dorpers also allows producers more flexibility in matching the feed requirements of the reproducing ewe to feed availability and allows mating systems to be altered according to seasonal conditions. Also, in many cereal-livestock production systems in Australia, lambing coincides with the seeding of crops. Labour shortages during this busy period mean that the sheep enterprise is often compromised resulting in lower than optimal energy intakes of ewes which consequently incurs production losses. Dorper ewes may be more “forgiving” in these situations than Merino ewes as they can better compensate for these shortfalls in energy intake by utilising their body reserves thus, again, allowing more flexibility for the farmer. One way that livestock production systems in Australia can adjust to increased variations in climate is by utilising the existing adaptations of the Dorper for a more resilient and flexible sheep production system.

Sheep farmers in Australia are being pushed to increase their stocking and reproductive rates in the face of labour shortages and climate change. The only way forward for the industry is to focus on producing fecund, robust and efficient sheep that are also easy-care. The Dorper fits all of these criteria well so could have an important role to play in the future of the livestock industry in Australia. However, more research into the Dorper breed is needed for this to be achieved.

7. Future research

This review agrees with other reviews that have been conducted on Dorpers in that there is a severe scarcity of scientific information on the breed, its performance under different management systems and how to optimise it production potential (Brand, 2000Brand, 2000; Cloete et al., 2000; de Waal and Combrinck, 2000; Schoeman, 2000). Although the population of Dorpers in Australia has increased, there has only been one study that has looked at the production of pure-bred Dorpers under Australian conditions (Kilminster and Greeff, 2011). As this study showed, Dorpers need to be managed differently to Merinos but as yet, we do not know the optimal and most cost-effective way to manage Dorpers under Australian conditions. The two most important areas that need further research are:

1. Develop a nutritional management plan to optimise reproductive rates in Dorpers
2. Investigate the ability of Dorpers to utilise low quality roughages and the possible production benefits in Australian farming systems.

1. Develop a nutritional management plan to optimise reproductive rates in Dorpers

The most important information that is needed is the optimum nutritional strategy for the Dorper ewe during reproduction since it is clear that the Merino strategy recommended in Australia is not optimum for the Dorper ewe. Although the basic concepts may be similar, the recommendations need to be adjusted for the differences in nutrient partitioning between the breeds. There are three main reproductive phases where the effects of targeted nutrition are needed:

1. Joining period to increase fertility
2. Late pregnancy and early lactation to optimise milk production and lamb performance
3. Late lactation/pre-mating to decrease period of post-partum anoestrus

Similar to previous work done for Merinos, optimal condition score and live weight change during pregnancy and lactation needs to be determined for Dorpers. From the data presented in this review, it could be hypothesised that the increased body reserves of Dorper ewes allows them to lose more weight than Merinos during late pregnancy and lactation before there are detrimental effects on their lamb. Therefore, rather than meeting their energy requirements during late pregnancy and lactation, it may be a more efficient use of feed resources to allow Dorper ewes to utilise their body reserves more during lactation, then increase feeding level pre-joining so that body reserves can be replenished. In the accelerated mating system of the Dorper, it is imperative that ewes return to oestrus as soon as possible after lambing. Therefore, the effects of nutrition on post-partum anoestrus also need to be investigated. In order to use feed resources most efficiently, the optimal level of feeding for production gains in reproducing Dorper ewes need to be established.

2. Investigate the ability of Dorpers to utilise low quality roughages and the possible production benefits in Australian farming systems.

The second research priority for Dorpers should be their utilisation of low quality feeds. In many sheep production systems in Australia, sheep graze low quality pasture or crop stubbles for around 6 months of the year, or more in the case of rangeland farming systems. Dorpers may be able to utilise these low quality diets better though increases in digestive efficiency or though diet selection and grazing behaviour because they may be more willing to consume the lower quality components of the available feed resources. The digestive efficiency of Dorpers needs further investigation to determine if differences exist in Australian grazing systems and the mechanisms behind these differences. The most important information that farmers need to know is to what degree these differences result in increased weight gain or decreased weight loss of Dorpers compared to other breeds when consuming low quality diets.

Both of these research priorities test how resilient the Dorper breed is to nutritional hardship. The ability of sheep to cope and adapt to changing environments is as important now as it will be in the future. Using sheep that have been bred to cope in harsh conditions such as the Dorper could be a valuable tool in the toolbox for farmers in the face of climate change.

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