The Effect of Breed on Feed Intake and Feed Efficiency in Merino and Maternal Type Ewes

By

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I declare this thesis is my own account of my research and contains as its main content, work which has not been previously submitted for a degree at any tertiary education institution.

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Abstract

Although Merino ewes dominate the Australian sheep flock, approximately 45% of lambs are born to non-Merino ewes. The Lifetime Ewe Management (LTEM) program has brought with it great advances to the sheep enterprise but as those guidelines have been tailored to Merino ewes, there is very little evidence to propose that non-Merinos ewes can be managed under the same guidelines. Our experiment hypothesised that maternal type ewes will have a lower maintenance energy requirement than Merino ewes, and that maternal type ewes will consume more feed than Merino ewes when fed under *ad libitum* conditions. Fed a pelleted diet, the feed intake and liveweight change of 40 ewes (20 Merino and 20 Greeline) was monitored over 42 days while they were housed in individual pens at the Murdoch University animal house. Of those 20 ewes in each group, 10 were fed a maintenance diet as per LTEM guidelines and 10 were fed *ad libitum*. Results found there to be no significant effect of breed on feed intake and maternal type ewes did not have a higher feed intake when fed an *ad libitum* diet either, hence not supporting either of the two hypotheses. Feed intake was rather found to be more related to liveweight. In conclusion, further research will need to be conducted in order to gain closer understanding of maternal type ewes and identify which traits in particular account for their performance differences.

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Literature Review

Agriculture is Australia's second largest industry (after mining), and livestock contributes to 60-70% of its gross value (Cottle, 2010). Although the sheep flock is at its lowest in over a century, Australia is one of the key players in the global trade of sheep with export demand accounting for over 50% of our produce (Manton-Pearce, 2013), making it the world's second largest sheep meat exporter and the largest producer of high quality apparel wool, altogether making the sheep industry worth approximately $6 billion (Cottle, 2010). Over the past 30 years the sheep industry has started to decline due to massive advances in cropping techniques. Sheep work still being relatively labour intensive, farmers have been inclined to concentrate more time, energy, money and resources on crop farming instead of sheep farming. Yet with demand for sheep meat and wool increasing, sheep farming must be sustainably continued in order to meet that demand.

"Sustainable sheep farming" could have various definitions for different people in the industry, but ideally it would comprise of a constant demand of produce, advances in sheep handling and/or management equipment and techniques, generous climate conditions, adequate supplies for both the farmers and their flock, and most significantly, advances in scientific research in order to understand the nutritional requirements, behaviour, management, physiology and reproduction of not only

sheep in general but with a focus on the individual breeds which are dominant in Australian flocks.

The Western Australian flock is predominantly Merino sheep, comprising approximately 84% the total flock, currently 13.8 million (Pritchett, 2016). The remaining proportion of the population comprises of British and Merino crossbreds, dual purpose (meat and wool) breeds and high-quality meat breeds (Pritchett, 2016). The majority of research examining sheep has been centred around the Merino breed and extension guidelines originating from the Lifetime Ewe Management (LTEM) program are tailored to the Merino ewe. The LTEM guidelines have made transformational changes in the Merino sheep industry and have had a significant impact on enterprise productivity, yet it cannot be assumed that managing non-Merino sheep the same as Merinos will give the same outcome. Although around 20% of LTEM program participants have reportedly achieved similar productivity gains when managing their non-Merino ewes based on the Merino ewe guidelines (Trompf *et.al*, 2011), recent work has identified possible components contributing to create errors in whole farm analysis with maternal sheep enterprises (Thompson, 2016). Those components include potential feed intake, relative feed intake associated with quantity of feed on offer, energy required for maintenance, the efficiency of energy use for maintenance and the energy content of the weight gain and loss.

This study looks at the feed intake aspects of both the Merino and Greeline breed. The Greeline breed is a composite maternal type breed originating from New Zealand comprising of ¼ east Friesian, ⅜ Texel and ⅜ Coopworth. Although it is mainly a meat breed, it has adequate wool quality and having a bare head and legs, it is easy to shear, saving some labour. This study was carried out over 42 days with 40 adult ewes; 20 Merino and 20 Greeline. The ewes were randomly allocated into individual pens and the diet group. Ten ewes of each breed were fed a balanced diet according to the LTEM guidelines to maintain bodyweight. The remaining ten were fed an *ad libitum* diet at 120% of their maximum feed consumed in the preceding 7 days. The hypothesis of this study was that maternal type ewes will have a lower maintenance energy requirement than Merinos when managed to maintain liveweight. Also, we predicted that the maternal type ewes will consume more feed than the Merinos when fed under *ad libitum* conditions.

Significance to the Industry

The significance of the Australian sheep industry is important to outline as it is what drives most of the scientific research done in this field. The report "Maintaining our Share of the Lamb Meat Pie" by Manton-Pearce (2013) outlines what the future holds for Australia's lamb market. Future drivers, current demands, emerging markets and opportunities to capitalise on the growing demand were some of the topics covered. Sheep meat, whether that be lamb, hogget or mutton, is the primary animal-sourced protein for most parts of the world. Middle Eastern countries, China, India, Australia, New Zealand, France, Greece and the United Kingdom are the nations with the

highest consumptions. With predictions for the Asia Pacific region to consist of more than half the world's population by 2050, it presents an enormous challenge for food security. Asia's food demand is expected to double by that 2050 mark, with China accounting for 43% of those demands and India 13%. Accounting for 90% of the world's global quantity, Australia and New Zealand are the leading lamb exporters.

An analysis by the Department of Agriculture and Food Western Australia (DAFWA), now known as the Department of Primary Industries and Regional Development, based on a data collated by the Australian Bureau of Statistics in catalogues 7125 and 7218 displays that approximately 30% of Western Australian sheep are exported live, with the remaining 70% slaughtered domestically (Pritchett, 2016). Approximately 28% of that proportion is consumed domestically with the remaining 72% exported as chilled meat mainly to China and the Middle East (Pritchett, 2016). The statistics presented in Manton-Pearce's report and DAFWA's analysis clearly suggest that both Australia and New Zealand have a great responsibility to meet global demands. Both Merino and Greeline breeds are prime meat breeds and further research in their feed management will not only provide benefit at the local scale for on farm productivity, but also the industry as a whole, justifying why research such as this project is important and will be beneficial for the Australian sheep industry.

Breed Differences

Limited literature is available regarding sheep energy requirements with regards to breed differences. Most of the studies that have been conducted and literature which is available is either less relevant to the Australian sheep production system, or is over two decades old. As the Merino genotype has changed significantly over the last few decades, such literature may not represent the current situation and circumstances. The following literature explores how differences between breeds affect feed intake, reproduction, wool production hence overall sheep enterprise production.

The 2013 Meat and Livestock Australia (MLA) Final Report by Babiszewski and Hocking Edwards analysed the potential industry impacts of managing non-Merino ewes. The report states that following Merino management guidelines and tools, particularly the LTEM program, could possibly be hindering the full performance potential of non-Merino sheep. The paper had stated non-Merinos to have a lower energy requirement in comparison to Merinos. An integral component of enhancing efficiency is to accurately predict the nutritional and energy requirements of sheep, and ration formulation software tools such as GRAZPLAN® and GrazFeed® are not suitably accurate for non-Merinos. This may result in over or under estimation of energy requirements, as the models may not take breed differences into account as accurately. This has been demonstrated by Thompson *et.al* (2017) in the Lifetime Maternals project where it sates *"During the analysis* [of the Components of the energy and intake equations] *carried out to determine the optimum liveweight*

profiles for maternal *ewes it was concluded that the equations used to predict energy requirements and intake capacity of the* maternal *ewes didn't represent the liveweight measurements taken in the trials and didn't align with anecdotal observations of the performance of the* maternal *breeds in the paddock".* This overestimation may result in wastage of feed and other resources such as labour, which may affect the producer's budgeting. One of the biggest profits drivers is stocking rate, therefore understanding energy requirements and availability allows the farmer to maximise their stocking rate. The estimation of maintenance energy requirements of sheep has not recently been revisited. In Northern Ireland, Dawson and Steen revaluated the maintenance energy requirements of beef cattle and sheep in 1998 after the last time it was done in 1990. The results showed there to be a 32% increase in the nutritional requirement in 1998 since 1990, suggesting that estimated maintenance energy requirement guidelines should be updated frequently in order to accurately feed sheep and meet their nutritional needs without wasting feed and resources.

The relative efficiency of Merino and first cross Merino/Border Leicester ewes was tested in a trial conducted by Kleeman and Dolling in 1978. The study shows the effect of breed on feed efficiency and also wool production, reproduction and feed efficiency of their progeny. The ewes, mated to Poll Dorset rams, were fed an *ad libitum* diet of Lucerne pellets during late gestation and early lactation. Each of the single-born offspring were slaughtered at a liveweight of 33kg. The comparison of efficiency between breeds were observed by exploring the efficiency of the ewe

(feed intake and production of clean wool), the lamb, (liveweight gain and milk conversion ratio), and the ewe-lamb unit (liveweight gain and weight of the carcass per unit of intake). The results demonstrated that the crossbred ewes consumed 7% less feed than the Merino ewes and produced 27% less clean wool. The Merino wool quality was superior to the crossbreds' with a lower fibre diameter and a higher crimp frequency. The progeny of the Merino ewes had a more efficient milk to body tissue conversion rate than lambs from the crossbred ewes but required an additional 25 days to grow to the desired slaughter weight of 33kg and ate 110% more organic matter over the entire period (when introduced to solid feed) than the crossbred ewe progeny. Ultimately, the study found the Merino ewe to be more efficient in producing clean wool than the Merino x Border Leicester ewe, and also to be slightly more efficient in its feed conversion ratio.

From 2005 to 2007, Kilminster and Greeff conducted a study in Western Australia to evaluate the reproductive performance between the Damara, Dorper and Merino sheep breeds when managed under the Lifetime Ewe Management guidelines, which are based on the requirements of Merino ewes. The Damara, Dorper and Merino ewes weighed 41.2kg, 42.4kg and 33.3kg, with body condition scores of 2.3, 2.4, and 1.8 respectively. When mated as lambs (at 8-9 months) the weaning rates were 71% for Damara ewes, 81% for Dorper ewes and 13% for the Merino ewes. The low weaning rate for Merinos was ascribed to low liveweight and body condition scores in comparison to the other two breeds. In the second year, the Damaras, Dorpers and Merinos weighed 61.9kg, 69.5kg, 61.6kg and body condition scored 2.8, 3.3 and

2.8 respectively. Their respective weaning rate was 52%, 122% and 177%. The final year results showed similar patterns as the second year with weaning rates resulting as 64%, 105% and 134% for Damara, Dorper and Merino ewes respectively. All together the Merino ewes weaned the most lambs throughout this experiment. The pattern in the results show that the Damara and Dorper ewes had a better reproductive performance as lambs but this decreased over time. Because all the ewes were being fed and managed under the Lifetime Ewe Management Merino based regime, it resulted in an increased level of fatness, particularly tail fatness, in the non-Merino fat tail breeds. This suggests that the ability for the fat tail sheep to consistently maintain high weaning rates decreased as body fatness increased. Overall, this study emphasised that there are major differences in the reproductive performance between breeds and for the best and more efficient on-farm results, non-Merino ewes should not be managed under Merino based guidelines because farmers often overestimate their nutritional requirements and are not optimal for those breeds.

Feed Intake

One of the main aspects of this experiment is to observe the feed intake of ewes. Whether rearing conditions are intensive or extensive, small ruminants such as sheep and goats are most commonly fed *ad libitum*. For that reason, the sheep's voluntary feed intake (VFI) is critical and optimising VFI is a fundamental point to attack when implementing feeding and management strategies. The following literature will

provide an insight to the previous work that has been completed in the field of sheep feed intake.

A paper by Pulina *et.al* in 2013 discusses factors which affect the VFI. Factors contributing to the effects of a sheep's VFI are considered to be genetics, hormones, the neuroendocrine system, type of feed and environmental factors. Measuring VFI is quite difficult and therefore requires a large database to estimate its heritability, and due to this and the expense very little research has been conducted in that area. There are a number of papers that demonstrate the heritability of VFI, for example Cameron (1998), Gullivan and Sullivan (1994), Francois *et.al* (2002), Cammack *et.al* (2005), Lee *et.al* (1995), Fogarty *et.al* (2009) and Snowder and Van Vleck (2003). Cammack (2005) found the lowest heritability of 0.11, whereas Cameron (1998) found heritability to range from 0.14 – 0.59. Overall Pulina concluded that the heritability of VFI to range from 0.10 to 0.60. The large range is assumed to be due to varying environment and experimental conditions. Another factor that affects VFI is said to be neuroendocrine and hormonal factors. Wild herbivores divide their foraging attention between searching for food and also escaping from predators, yet the grazing behaviour for domesticated ruminants, such as sheep, is controlled by psycho-physiological factors only as the danger from predators is generally eliminated. Psycho-physiological factors are said to be factors which contribute to the level of satisfaction in regards to filling of the rumen. Factors regarding the feed itself, such as the nutritional value and filling effect, are key characteristics regarding VFI. The main physical factor that limits VFI is fibre content as fibre fills the rumen.

Hence a high fibre diet will most likely result in lower VFI than a low fibre diet. For grazing sheep, the sward height, pasture density and herbage mass are limiting factors of VFI (Forbes, 1995). Amongst the environmental constraints, the factors that limit VFI include temperature, photo period, topography and distance from the drinking water source (Pulina, 2013).

Body weight, breed, sex and feed composition are four other factors which research has found to affect the feed intake of sheep. An experiment conducted by Lewis and Emmans in 2010 explored the extent of the contribution of these four factors. Both sexes of two breeds (Suffolk, Scottish Blackface) and their first cross were used in this experiment, which was conducted over a five year timespan. They were fed *ad libitum* six diets of varying quality, high quality, Lucerne, low energy content, ryegrass, medium protein content and low protein content. The results showed that even after accounting for liveweight in the model, male sheep had a significantly higher intake than female sheep. Also, the scaled intake value for Suffolk was greater than that of the Scottish Blackface, with their crossbreed being intermediate. Suffolk males were fed the high quality; medium and low protein diets, with results displaying a respective descending pattern in the scaled intake and metabolisable energy. Suggesting that metabolisable energy was highly correlated with intake for each diet. The low energy, Lucerne, ryegrass and high quality feed was fed to both sexes of all breeds. The results again displayed a respective descending pattern of scaled intake, but contrastingly, there was a respective ascending pattern for the metabolisable energy.

Grazing systems and specific grazing management tools are considered to be very helpful to maintain and improve long term production of livestock such as sheep and cattle as a way of better management and maximising productivity. Research performed by Dickhoefer *et.al* (2014) analysed the digestibility of ingested forage, feed intake and live weight gain of sheep in a semi-arid grazing environment at different grazing intensities. The results showed that the grazing system did not have any effect on the digestibility of the organic matter and live weight gain of the sheep, nor was there an interaction between grazing system and grazing intensities. In conclusion, the study suggested that although grazing systems, such as rotational grazing, did not improve digestibility or intake, hence no liveweight gain, it might enhance revenue and promote pasture sustainability in comparison to continuous grazing at a high stocking rate.

Digestibility

There are a few theories regarding the differences between the energy requirements of Merinos compared to non-Merinos. A study by Freetly *et.al* (1995) suggests that maturation rate differences between breeds can be a reason behind energy requirement dissimilarities. Freetly found slower maturing breeds will have a higher metabolism at the same age as faster maturing breed, accounting for differences in their energy requirements. Gastrointestinal tract morphology has been found to be different between breeds not only in sheep but also other ruminants such as cattle (Kennedy, 1982). Varying morphology of the gastrointestinal tracts allows some

breeds to be able to extract more nutrients from certain feeds than other breeds (Kennedy, 1982).

In contrast, Ranilla *et.al* (1997) compared the ruminal activity of the Churra and Merino sheep that were offered an alfalfa hay based diet. The results showed that the degradation of dry matter and cell wall was greater in the Churra breed when compared to the Merino. The differences were shown to be greater when associated with a particular ruminal environment. The pH of the rumen was found to be higher and the ammonia concentration was lower in the Churras as opposed to the Merinos, whereas rumen volatile fatty acids were usually higher in the Merinos than the Churras. These differences in rumen characteristics were only seen to be significant before feeding. Overall the results suggested that the fibre-degrading microorganisms, which reside in the rumen, had a higher activity rate in the Churras in comparison to the Merinos, and this possibly could be a result of the Churra breed's ability to maintain a more stable and optimum rumen pH, which creates a favourable environment for the digestion of nutrients, fibre in particular.

Further to this, work by Lopez *et.al* (2001) aimed to examine the digestibility and rumen's degradation differences between the Merino and Churra sheep in Spain. The fresh herbage diet was harvested at two separate maturity stages and was fed so that each sheep's feed intake level ranged from 8.1g to 24.7g of dry matter per kilogram of body weight per day. The results showed that although the Churra breed had a slightly higher dry matter digestibility than the Merino breed for both the early

and late cuts of herbage, the difference between the dry matter digestibility of those two breeds was insignificant. In conclusion, the study demonstrated that comparing the differences of digestibility between breeds is highly dependent on the diet, however increasing feed intake resulted in a higher supply of microbial mass in the digestive system, particularly in the small intestine, suggesting that it could enhance the efficiency of microbial synthesis in the rumen.

A similar experiment was conducted in Australia in by Wilkes *et.al*, (2012). The study was conducted to explore the feed utilisation efficiency and growth performance of the Damara and Merino breeds when managed under two contrasting levels of nutrition. The wethers from each breed who were fed a low quality diet, followed by a high quality diet under *ad libitum* conditions. The results displayed that although the Damara wethers had a similar feed intake as the Merino wethers, their dry matter digestibility was approximately 10% higher than Merinos. On the high quality diet, the results showed that Damara wethers had a 14% higher consumption rate than Merinos but no apparent difference was found in the dry matter digestibility of those sheep. Overall, the Damara carcasses were found to be 22% heavier and have a slightly higher dressing percentage than the Merino carcasses while the proportion of the carcass components did not vary between the breeds. In conclusion, the Damara wethers attained a higher total digestibility and a higher voluntary feed intake than Merino wethers on both diets and also were able to digest more of the low quality feed. The researchers postulate that the reason behind the greater feed intake of the Damara weathers arises from variation of rumen volume and site of

digestion. It has been demonstrated that there are breed differences in gut morphology, retention time and digestibility that may contribute to animals having higher or lower requirements for feed. These differences may be expressed as greater liveweight gain or reproductive outputs and will have an effect on profit in Merino versus maternal farm enterprises.

Hegarty *et.al*. (2004) carried out an experiment with both sheep and cattle to explore differences between breeds and how those differences can have an impact on the digestive tract function of ruminants. All investigations in the project indicated differences in the digesta retention time between breeds suggesting that the ability to control and select for optimum ruminal retention time could be a useful trait in order to improve productivity. Differences in rumen retention time may alter the population and diversity of the rumen microorganisms and affect the production of volatile fatty acids which could in turn affect the amount of maintenance energy available and required. Other useful effects of increasing retention time include the possibility of reducing methane production and also increasing the synthesis of long chain fatty acids, which could further improve efficiency. Despite evidence that there is genetic diversity in rumen function, the actual importance of ruminal retention time has not been fully examined.

Whole Body Fatness and Body Condition Score

As the following literature and studies show, whole body fatness and good body condition score could be seen as good indicators of higher feed intake and feed efficiency. Blumer *et.al* 2016 explored the effects of whole body fatness in adult Merinos when fed a poor quality diet. Ewes were fed *ad libitum* feed, aiming to maintain liveweight, or a restricted amount of feed, with the aim to achieve a weight loss of 100g per day. The study hypothesised that ewes with a higher proportion of fat would perform more efficiently at both feeding levels. When adjusted for liveweight and liveweight change there was a difference of 2 MJ of ME per day between the most efficient and the least efficient ewes for feed intake. When adjusted for feed intake, there was a difference in liveweight change of 90g per day between the most efficient and the least efficient ewes for liveweight change. A significant outcome from the results was the association of leptin concentration in blood plasma with feed and liveweight gain efficiency. Ewes with higher leptin concentrations were found to have a lower voluntary feed intake and had less weight loss in comparison to ewes with lower leptin levels. The paper concluded that work needs further testing with more varied feed types, environments and production systems. Yet overall it can be concluded that whole body fatness could be used as a predictor of liveweight efficiency for adult Merino ewes when fed a diet of low quality. Using genetics or nutritional management techniques to maximise fat tissue deposition could be beneficial for ewes especially from summer to autumn as that is the time of year in Mediterranean systems that pasture availability declines, meaning fat deposits could temporarily reduce feed demand at this time.

Tolkamp *et.al*. (2006) conducted a similar experiment to quantify the effects of body weight and body condition score on average daily feed intake. Greyface and Texel crossbred ewe lambs were fed two of the following diets: high quality feed of barley, medium quality feed of oats and low quality feed of chaff. The results showed that lambs fed the medium quality oat based diet consumed more feed than those on a high quality barley based diet so that metabolisable energy intake was not significantly different and the lambs did not differ for liveweight gain or body condition score. However, ewe lambs which were fed a low quality chaff diet displayed compensatory feed intake and weight gain when switched to a medium or high quality diet. When feed quality was downgraded from a high or medium quality to low quality, the lambs lost body condition score and liveweight. The study concluded that although body fatness affects the feed intake of sheep at a particular body weight, it single-handedly is an insufficient description to predict feed intake. Estimates of feed intake can be improved by taking body condition score into consideration as well. However, this does not necessarily suggest that body condition score and body weight are the only factors implicated in predicting the feed intake of sheep.

Conclusions

The summarised literature presented in this literature review gives an insight into some of the factors contributing to feed intake and efficiency in small ruminants. Although extensive research has been carried out examining breed differences and

feed intake, not many have observed both topics in one study or compared the breed types commonly farmed in Australia. There are gaps in small ruminant research which should be filled by further research in order for the findings to be implemented on-farm and enhance productivity and profit.

Conclusions drawn from this literature review indicate one point in particular, which is that non-Merino sheep cannot be managed using the same guidelines as Merinos, as the nutritional requirements are not matched. When managed under the Lifetime Ewe Management recommendations, the requirements of non-Merino sheep are often overestimated leading to wastage of feed, resources and labour.

This study will be exploring breed differences in feed intake and efficiency. With the population of non-Merino sheep increasing in our Australian flocks, correct management guidelines and breed focused research would be highly beneficial for farmers as well as the Australian sheep industry overall.

Introduction

Optimum management guidelines for breeding Merino ewes have been developed and adopted by sheep producers throughput Australia to increase productivity, profitability and animal welfare. Currently approximately 45% of lambs produced are born to non-Merino ewes (Hocking Edwards *et.al*, 2016). Farmers who run non-Merino flocks have achieved similar gains++ in production and profitability while managing their non-Merino ewes according to Merino guidelines (Trompf *et.al,* 2011), however, there is little evidence to support that they can be managed to optimise performance under the same guidelines as both breeds generally perform differently when managed together.

Extensive studies have been performed which examine breed differences and feed intake, not many have explored both aspects in the one study, especially in the Australian sheep farming system. The Lifetime Maternals project is one of the major research projects in Australia that is similar to the Lifetime Ewe Management (LTEM) project, which has observed ewe liveweight change, gestation condition score, lamb birth weights, lamb survival and weaning weights (Thompson, 2017). Babiszewski and Hocking Edwards (2013) reviewed the difference between Merino and non-Merino ewes when managed under the same nutritional conditions. Results showed that the non-Merino ewes have 13-34% more wool growth and produce 36% more milk than Merino ewes. The non-Merinos were also found to have higher fertility,

fecundity and maternal efficiency than Merinos, along with not only higher weaning percentage but also heavier lambs. Hocking Edwards *et.al* (2017), Berehndt *et.al* (2017) and Thompson *et.al* (2017) have demonstrated that maternal type ewes perform better for liveweight efficiency when compared to the expected outcomes for Merino ewes. Babiszewski and Hocking Edwards (2013) concluded that non-Merino ewes have a lower feed requirement in comparison to Merino ewes and this may explain why they perform better than expected. This could also be as a result of many factors such as body weight, breed, sex, feed composition (Lewis & Emmans, 2010), gastrointestinal tract morphology (Kennedy, 1982) and some environmental factors. Previous literature by Thompson (2017) found that liveweight change was higher for maternal type ewes than expected. This difference in liveweight gain could be delivered by several mechanisms, including more efficient use of feed and nutrients, and increased level of potential intake. Therefore, we hypothesise that maternal type ewes will have a lower maintenance energy requirement, and consume more feed than Merino ewes when fed under *ad libitum* conditions.

Method and Materials

Selection of Ewes

Intake and liveweight changes were measured in Merino and maternal type ewes managed in single pens on two different diets for 42 days. Adult dry ewes were sourced and transported to the Murdoch University feedlot, consisting of 30 Greeline ewes and 28 Merino ewes aged between 4-6 years. The Merino ewes were sourced from the Department of Agriculture and Food Katanning Research Facility and were previously part of Greeff *et.al*, 2013 breech strike experiment. The Greeline flock were sourced from Glenridge in Mt Barker (David and Lyn Slade) and were previously part of the Lifetime Maternals experiment. The ewes were brought to the Murdoch University feedlot facility approximately 4 to 5 weeks prior to commencing the experiment and had access to *ad libitum* hay. Ten days prior to the experiment, the ewes were introduced to pelleted feed, starting at 50g/h/d (per head per day), then increasing by 100g/h/d until the experiment commenced. Their liveweight was monitored three times a week leading up to day one of the experiment. Twenty ewes of each breed were to be selected, with outliers of liveweight removed from the experiment. All experimental work was carried out with the approval of the Murdoch University Animal Ethics committee (Approval Number R2891/16).

Housing/Pens

All ewes were housed at the Murdoch University Animal House which has been designed for sheep with open walled pens allowing the sheep to see each other clearly. The pens are supplied with nipple water feeders and are raised with a grill floor over concrete. The individual pens were 1.45m x 0.87m in size and made of metal piping.

Management and measurements

Ewes were balanced for liveweight and condition score before being allocated to a diet group so that each of the four breed by diet groups consisted of 10 sheep each. Ewes were then randomly allocated to a pen. At the commencement and completion of the trial a 24-hour fasting liveweight was collected. For a total of 42 days, the weight of each trough was recorded and then emptied before fresh pellets were delivered. All ewes were weighed three times weekly in order to measure liveweight change, and condition scored by the same operator once per week. Daily liveweight change was predicted using a linear regression of all liveweights against time in order to reduce noise in the weight data (Day 3-45; not including the fasted weight).

Diet

The ewes were fed Morgan Feed Supplies' Prime Lamb Pellets. The ingredients include wheat, lupins, barley, cereal by-products and cereal straw/ hay, ground limestone, molasses, salt and a vitamin/trace mineral premix. Its nutritional

composition consists of crude protein (15%) metabolisable energy (11 MJ/kg), fibre (25%), added salt (0.4%) calcium (1%), mineral premix (2%). The ewes fed *ad libitum* were fed twice the maintenance diet as per LTEM guidelines. The ewes were then fed 400g/h/d extra until there were consistently refusals in the trough. They were then fed 120% of the maximum intake over the previous 5 days and the maximum value was adjusted on a daily basis. The ewes fed maintenance were fed initially according to the LTEM guidelines and were thereafter adjusted following every liveweight measurement in order that they achieve liveweight maintenance.

Statistical analysis

All statistical work was conducted using SAS (SAS Institute, 2004). The base models testing metabolisable energy intake and daily liveweight change as separate dependent variables included the treatment fixed effects; diet (*ad libitum* and maintenance) and breed (Greeline and Merino). Animal level models included starting liveweight as a covariate. All models included the first level interactions between the fixed effects and if included, the fixed effects and the covariates. Non-significant terms ($P>0.05$) were removed in a stepwise fashion, however the treatment fixed effects were retained even if non-significant.

The residuals from a model explaining intake with liveweight and liveweight change can be used to represent efficiency, so that the unexplained variation is termed Residual Feed Intake (RFI). With liveweight and liveweight change accounted for,

animals with negative residuals are consuming less than expected as per the cohort mean, while an animal with positive residuals is consuming more than expected. RFI was analysed as a dependant variable to indicate the range of efficiency in this trial. The model tested the treatment fixed effects (breed and diet), as well as condition score as a covariate. All first order interactions were included and non-significant terms ($P>0.05$) were removed in a stepwise fashion.

Finally, the MANOVA procedure was used to test the relationship between the Australian Ruminant Feeding standards prediction for each maintenance ewe within breed, and actual feed intake.

Results

Merino ewes entered the animal house with an average liveweight of 55.4 kg (± 4.13) while Greeline ewes were 63.6kg (± 4.44). Ewes fed a maintenance diet for 42 days did not gain liveweight (0.007 kg/day ± 0.02), although ewes fed *ad libitum* increased liveweight (0.2736 kg/day ± 0.02; $P<0.05$). There was no significant difference in liveweight gain between breeds fed *ad libitum* and maintenance diets.

Diet had a significant effect on feed intake ($P>0.001$), with ewes fed at maintenance consuming 6.56 (± 0.66) MJ of ME per day and ewes fed *ad libitum* consumed 16.56 ± (0.66) MJ of ME per day. There was no difference in average feed intake between breeds on either the maintenance diet (6.8MJ of ME/day (± 0.93MJ) vs 6.3MJ of ME/day (± 0.93MJ); ($P>0.05$)) or the *ad libitum* diet, (17.9MJ of ME/day (± 0.93MJ) vs 15.2MJ of ME/day (± 0.93MJ); ($P>0.05$)) for Greeline and Merino ewes respectively.

There was a significant ($P<0.001$) effect of starting liveweight on average daily feed intake (Figure 1.). A 5kg increase in fasted liveweight at the start of the experiment corresponded to an increased intake of 1.2MJ of ME/day for ewes consuming a maintenance diet. There was no significant interaction between diet and starting liveweight, displaying that ewes on the *ad libitum* diet consumed approximately 2.7 times the MJ of ME/day provided to ewes for liveweight maintenance.

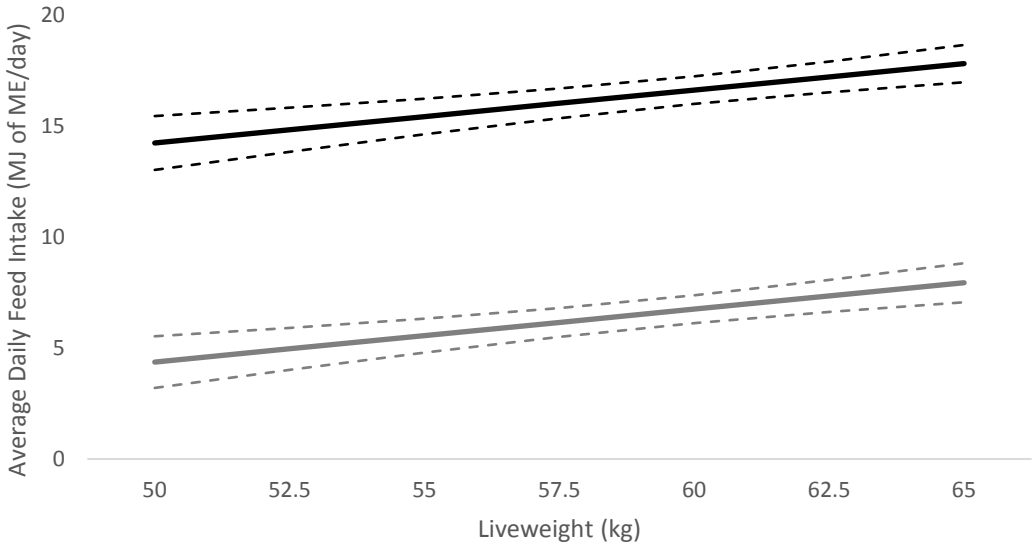

Figure. 1. The effect of initial fasted liveweight (kg) on Average Daily Feed Intake (MJ of ME/day) for both Greeline and Merino breeds fed on either *ad libitum* (black line) or maintenance diet (grey line) over 42 days. Dashed lines represent ± standard error.

When intake was modelled within breed it was significantly different for both breeds, to the maintenance requirements derived from Lifetime Ewe Management (and the Australian Ruminant Feeding Standards) for ewes in confinement feeding (figure. 2). Liveweight explained 82% of the variation in feed intake for Merino ewes consuming a maintenance diet ($P<0.001$) but did not significantly explain the variation for Greeline ewes at maintenance ($r^2 = 0.56$; $P=0.09$).

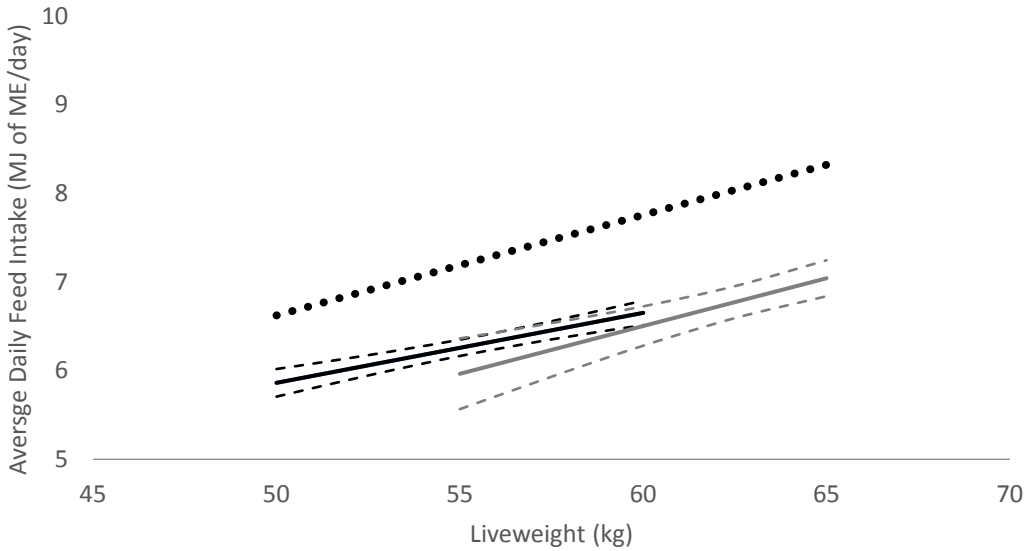

Figure. 2. The effect of initial fasted liveweight (kg) on average daily feed intake (MJ of ME/day) for Greeline (grey line) and Merino (black line) ewes fed on a maintenance diet (modelled within breed), compared with the Lifetime Ewe Management predicted guidelines (thick black dotted line). Dashed lines represent ± standard error.

When variation accounted for by liveweight and liveweight change was removed by modelling residual feed intake, condition score was found to have a significant effect on the relative efficiency of ewes so that ewes at condition score 2.75 consumed 1.9MJ of ME/ day more than ewes at CS 3.75 ($P<0.05$; Figure 3).

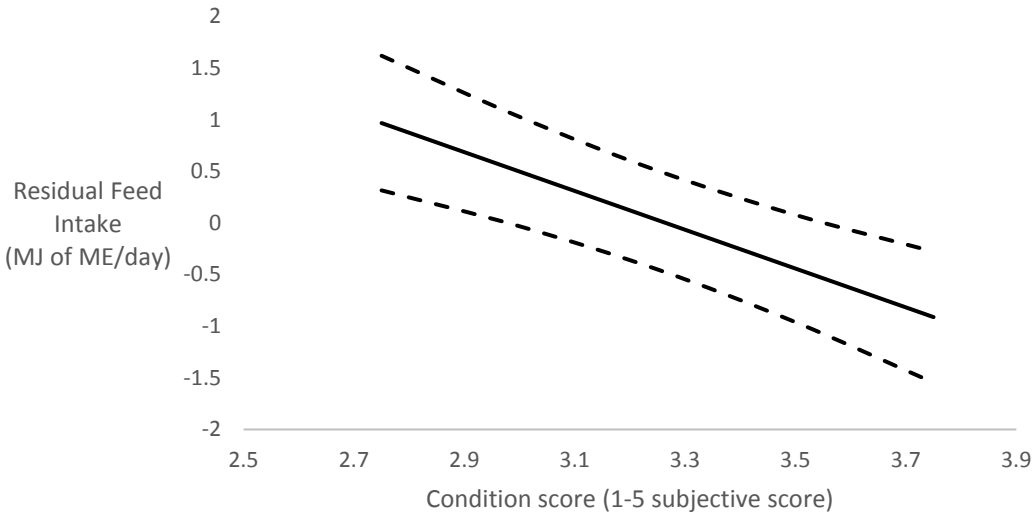

Figure. 3. The effect of condition score on Residual Feed Intake (MJ of ME/day) to explore feed efficiency. Standard errors (±) represented by dashed lines.

Discussion

Potential feed intake under *ad libitum* conditions did not differ significantly between adult maternal and Merino ewes, and feed intake was simply related to liveweight regardless of ewe breed. Previous studies have demonstrated that maternal type ewes have a higher feed intake than Merino ewes when managed under the same grazing conditions, therefore we predicted that maternal type ewes will have a higher feed intake when fed under *ad libitum* conditions. A possible explanation could be that maternal type ewes have a greater appetite and simply consume more. However, this hypothesis was not supported by our experimental data, although results from this trial demonstrates that feed intake increases as liveweight does. A study performed by Blaxter *et.al* (1961) displayed similar results to us, where the feed intake of sheep was positively linear, therefore body weight and feed intake were proportionate. This conclusion is further supported by previous studies which suggest that *"the gut capacity of mammalian herbivores increase linearly with body weight"* (Demment and Van Soest, 1985). This indicates that there must be another mechanism, apart from breed differences, responsible for maternal type ewes performing better.

There was no evidence that the energy requirements for maintenance differed between adult maternal and Merino ewes. The second hypothesis was therefore also not supported. Given no differences in intake or maintenance requirements, differences in digestibility could be a key factor explaining why the maternal type ewes perform better than Merino ewes despite not having a higher intake. Although

found in cattle, differences in gastrointestinal tract morphology have been found across breeds and the varying morphology gives the animal the ability to extract different amount of nutrients from the same amount of feed (Kennedy, 1982). Wilkes *et.al* (2012) also has demonstrated that there are breed differences in gastrointestinal tract morphology, retention time and digestibility which may contribute to animals having a higher or lower feed requirement. This difference between breeds may be more evident when consuming different diets rather than the highly digestible and palatable pelleted diet provided in this experiment. A study by Lopez *et.al* (2001) demonstrated that comparing digestibility differences between breeds can be highly dependent on the diet. This was evident when our results were compared to results from Blumer *et.al* (2016) where their *ad libitum* fed ewes were fed a low-quality diet of barley straw chaff, supplemented with a mineral mix and whole lupins. The average daily feed intake was 1.34kg dry matter/day (DM/day), which was approximately 2.32% of their liveweight. In our experiment, however, the average intake was 1.68kg DM/day; 2.8% of their liveweight. While the ewes in both experiments consumed fairly similar proportions of their liveweight in feed, the metabolisable energy intake was significantly higher in our study (16.02MJ or ME/day) than in the trials by Blumer *et.al* (2016) (6.2MJ of ME/day). As pellets are more palatable than chaff, this comparison shows that type of diet and palatability could also be a key driver for difference in feed intake and metabolisable energy intake.

Feed intake and liveweight gain were strongly correlated on both *ad libitum* and maintenance diet types as those fed an *ad libitum* diet consumed approximately 2.7 times more feed than those fed a maintenance diet. Although, this difference ranges from 3.26 to 2.24, steadily decreasing as liveweight increases. It may be thought that the *ad libitum* diet could have a decreasing factor with liveweight, but because the feed (kg) as a percentage of liveweight ratio was consistently 2.98% throughout the experiment, it is more likely that the maintenance diet has an increasing factor with liveweight as the feed intake as a proportion of liveweight ranged from 0.91%, increasing to 1.28%. This indicates that when fed *ad libitum* there is more consistency in feed intake which is useful when implicated into a real-life farming system, as majority of ewes are fed *ad libitum*. Kleiber's law (Kleiber, 1932) states that an animal's metabolic rate is ¾ the power of the animal's mass ($q_0 \approx M^{¾}$; q_0 = Metabolic rate, M = mass). Basically, suggesting that because Greeline ewes are bigger in size compared to Merino ewes, they would have a higher metabolic rate and be more efficient than them as well, however they are not, as Greelines have eaten more for the same degree of liveweight change at maintenance, and the *ad libitum* consumption is the same across the range of liveweight. Energetically its more expensive to maintain muscle tissue than it is to maintain fat tissue, so it is possible that our larger ewes were leaner and had a higher proportion of muscle tissue, meaning that their energy requirements were higher. We have not been able to explain the reasons behind the results gained in the scope of this experiment hence further research needs to be conducted.

Fat and muscle composition has been previously demonstrated as a driver of efficiency (Blumer *et.al*, 2016) and while no difference was seen between the breeds, there was an effect of composition, as measured by condition score, on efficiency, but this occurred across both breeds. Level of fatness also influences efficiency as Blumer *et.al* (2016) found that ewes with a higher proportion of fat were more efficient. Dickerson (1978) also stated that less fat animals usually a higher daily energy requirement. Several factors such as visceral mass, protein turnover rate, efficiency of digestion, again, fatness and physical activity level have been seen to affect feed efficiency (Robinson and Oddy, 2004). Activity levels would be an reasonable explanation for the trends of our experimental data as well, because our ewes were housed in pens and had very little physical activity as they did not have to locomote to find and graze on pasture. Residual Feed Intake is a useful model to quantify production efficiency as it is a linear function of maintenance liveweight, feed intake and production (Van der Werf, 2004). A study performed by Herd and Arthur (2009) explored the 5 major RFI varying contributors. Physical activity was one of three physiological processes which explained 73% of the variation, indicating that level of physical activity does impact on feed intake and feed efficiency. The RFI model in our experiment displayed that condition score had a significant effect on the relative efficiency; as the ewe gained condition score, she became more efficient. Although it is a subjective measure, accurate body condition scoring can provide a useful estimation of fat proportions in ewes and those predictions can sometimes be superior to that suggested by liveweight indications (Russel *et.al*, 1969). As higher condition score is usually related to higher fat levels, our RFI model suggests that the

higher the proportion of fat, the more efficient the ewe, supporting findings by Blumer *et.al* (2016) and Robinson and Oddy (2004).

In this experiment all ewes consumed less than expected by the LTEM guidelines. As explained previously, the ewes were housed in individual pens, and the level of confinement feeding proposed that there would be reduced activity levels, hence conserving the energy that would be otherwise required for locomotion in order to find and graze on pasture. The MANOVA test prediction of maintenance energy was poorly correlated with the actual intake. The 56% correlation between the predicted and actual intake of the Greeline ewes indicates that there was a lot of noise in the data and if this experiment were to be replicated in the future, a larger sample size would be required.

The findings of this experiment indicate that further experiments will need to be performed to identify why maternal type ewes tend to perform better than Merino ewes. Tools, such as GrazFeed® and GRAZPLAN®, and management guidelines, such as Lifetime Ewe Management, need to be re-evaluated and readjusted in order to incorporate the requirements of maternal type ewes. Many studies have suggested that digestion and gastrointestinal tract morphology have large impacts on fee intake and feed efficiency. Further investigation of those factors will need to be conducted in order to gain closer understanding of maternal type ewes. To effectively improve this particular experiment, firstly a larger sample size can be used to achieve more significant results with less variance. Secondly, different feed types and

environments can be incorporated. A field trial, for example, will give a more accurate representation of a real-life on-farm scenario as the sheep will maintain their natural paddock behaviour. As there are various maternal type breeds in Australia, it would be beneficial that a variety of breeds be utilised. Once accurate nutrition and management guidelines are created and implied in real-life farming systems, it will positively impact the sheep farming enterprise as efficiency, productivity and profitability can be enhanced.

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